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ESTIMATING COSTS AND MANPOWER REQUIREMENTS FOR CONVENTIONAL WASTEWATER TREATMENT FACILITIES

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Data for estimating average construction costs, operation and maintenance costs, and manpower staffing requirements, are presented for conventional wastewater treatment plants ranging from 1 to 100 mgd in capacity, and for stabilization ponds ranging from 0.1 to 10 mgd in capacity. Estimating data are included for 21 separate components of conventional plants and 6 separate components of stabilization ponds. Examples of use of the data are given. Estimated average construction costs and operation and maintenance costs are related graphically to appropriate single parameters for respective plant components. Occupation descriptions for 24 job titles related to wastewater treatment, developed in accordance with standards of the Dictionary of Occupational Titles, are included ~~in the report~~. The data presented provide means of estimating costs and staffing requirements for a variety of conventional wastewater treatment facilities on an average basis, but do not supplant the need for detailed study of local conditions or recognition of changing design requirements in preparing estimates for specific application. (Lowry-Texas)

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FOR
CONVENTIONAL WASTEWATER TREATMENT FACILITIES

ok

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ABSTRACT

Data for estimating average construction costs, operation and maintenan costs, and manpower staffing requirements, are presented for convention wastewater treatment plants ranging from 1 to 100 million gallons per da in capacity, and for stabilization ponds ranging from 0.1 to 10 million gallons per day in capacity. Estimating data are included for 21 separat components of conventional plants and 6 separate components of stabiliz ponds. Examples of use of the data are given.

Estimated average construction costs and operation and maintenance cost are related graphically to appropriate single parameters for respective plant components. Occupation descriptions for 24 job titles related to wastewater treatment, developed in accordance with standards of the Dictionary of Occupational Titles, are included in the report.

The data presented provide means of estimating costs and staffing requirements for a variety of conventional wastewater treatment facilities on an average basis, but do not supplant the need for detail study of local conditions or recognition of changing design requirement in preparing estimates for specific application.

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CONCLUSIONS AND RECOMMENDATIONS

Average data for estimating construction and operating costs and manpower staffing requirements of conventional wastewater treatment facilities presented in this report are applicable as bases for preliminary estimates for planning requirements, general comparative studies of costs of alternative wastewater treatment methods, and estimates of total costs and manpower requirements to provide designated levels of treatment for wastewater effluents in an entire area, state, region, or watershed. These average estimating data, unadjusted for particular local conditions, cannot be considered applicable for specific treatment plant estimates.

Current practice in the design and operation of wastewater treatment plants is changing due to technological advancement, requirements for improved quality of plant effluents, and reliability. Estimates of average costs and manpower requirements, which are based upon recent practice, may need adjustment for recognition of changing requirements.

The limitations of average estimating data presented must be recognized by the user. Estimates based upon such data should be considered only of sufficient accuracy for use in reaching broad general conclusions. When used with sound judgment by knowledgeable estimators, the data are considered valid for their limited intended purpose.

It is recommended that recognition be given to the fact that data for estimating construction and operating costs, and manpower requirements, of conventional wastewater treatment facilities should be revised from time to time to reflect new design and operating practice required by changing technology.

INTRODUCTION

The Environmental Protection Agency, is charged with the responsibility of administering the Federal Government program for reduction of pollution of rivers, streams and lakes throughout the United States. This responsibility includes enforcement of water pollution control standards as well as the effort to assure that Federal grant-in-aid funds are used most effectively in reducing water pollution.

To assist in evaluating both proposed water pollution control projects and the effectiveness of existing facilities, the Environmental Protect Agency requested the preparation of this report on initial investment costs, operation and maintenance costs, and manpower requirements for conventional wastewater treatment plants.

PURPOSE

The purpose of this report is the presentation of data for estimating, on a preliminary basis: (1) the costs of construction and other initia investment costs of individual major components of conventional wastewater treatment plants; (2) the costs of operation and maintenance of individual components of such plants; and (3) the manpower requirements for staffing conventional treatment plants. Estimating data presented are appropriate for average conditions and, when used with judgment regarding specific local situations, should permit development of adequate preliminary estimates for conventional wastewater treatment facilities.

SCOPE

This report presents cost estimating data and manpower requirements for major components of conventional wastewater treatment plants. Major plant components included are typically raw wastewater pumping stations sedimentation basins, trickling filters, digesters, sludge dewatering, sludge incineration, and other facilities. Cost and manpower estimates for each component are related to a single parameter for sizes of individual facilities appropriate to treatment plants ranging in capacity from 1 to 100 million gallons per day. Use of estimating data shown in this report is dependent upon the design engineer establishing, on the basis of appropriate design criteria, the overall treatment process and sizes of components required for the particular treatment plant with which he is concerned.

It is essential that the user of estimating data presented in this report carefully review all introductory material, including the sectio on "Data Development," so that he may more fully appreciate the breadth of the estimating methods presented, and the limitations on accuracy and applicability for any particular situation.

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It must be recognized that the estimating data and methods presented in this report cannot in any way be used as a substitute for cost estimating based on detailed knowledge of a particular wastewater treatment plant situation. Thorough construction cost estimates must recognize not only the particular plant design characteristics and complexity, but also such items as current and projected labor costs, attitudes of proposed contractors regarding their need for work at the time of construction bidding, availability of materials, climate and seasonal factors, local site conditions, and many other variables which affect actual construction costs.

Operation and maintenance cost estimates presented are believed to be valid averages for sound operation of the plant components considered. It must be recognized that many local factors, each of which may be valid in a particular situation, can have a significant effect on operation and maintenance costs, and on manpower requirements. Therefore, the user of this report is urged to recognize its limitations, and to use the data presented with care and judgment.

The report is presented in four parts as follows:

Part One - Construction Costs
Part Two - Operation and Maintenance Costs
Part Three - Manpower Requirements
Part Four - Wastewater Stabilization Ponds

Part One presents data for estimating construction costs of 21 plant components as well as other initial investment costs such as engineering, land, administration, financing, and interest during construction for conventional plants. Proper application of the estimating data should permit the development of total project costs, such as may be required in preparing preliminary financing programs and grant-in-aid applications. Estimating data are presented in graphical form relating cost to an appropriate size parameter. An example application of the estimating data included is shown at the end of Part One.

Part Two presents data for estimating operation and maintenance costs of major components of conventional wastewater treatment facilities. Applicability of these estimating data to any particular situation must be carefully considered. An example of use of the operation and maintenance cost data is shown in Part Two.

Part Three presents the estimated manpower requirements for both operation and maintenance of given conventional plant components under average conditions. Estimated staff complements for 9 examples of typical wastewater treatment plants of conventional primary and secondary types are presented. Each example indicates, for given average conditions, the suggested number and types of personnel required to properly operate and maintain the facilities. Personnel positions are identified by appropriate occupation titles. Detailed occupation descriptions for the 21 categories of personnel which, in the judgment of the investigators, may be required for staffing conventional treatment facilities are shown. The occupation descriptions are developed in conformity with the Dictionary of Occupational Titles published by the U. S. Department of Labor.

Part Four presents, separately from the first three parts, initial investment costs, and operation and maintenance costs for wastewater stabilization ponds when used, not as a plant component, but as the total treatment process. The cost and manpower estimating data presented in this section are for stabilization ponds providing treatment capacity up to 10 million gallons per day. Three additional occupation descriptions applicable solely to wastewater stabilization ponds are included in Part Four.

DATA DEVELOPMENT

Information for estimating costs and manpower requirements presented in this report is intended to be applicable for average situations throughout the coterminous United States. Any estimating methods with such broad applicability must of necessity be regarded as suitable only for preliminary estimates of average situations. Such data cannot be considered to be specifically applicable to any particular situation.

Cost data and manpower requirements developed are based on the experience of the investigators, together with judgment as to the applicability of that experience to the particular matter for which costs and manpower requirements are analyzed.

Construction cost data are developed on the basis of extensive experienced data concerning design details and actual construction costs of a large number of wastewater treatment plant projects constructed during the period 1950 through 1968. Careful analysis of information of record, as described in Part One of this report, provides a basis for evaluation resulting in the graphical cost relationships presented. While costs of specific projects are not individually represented by average estimates, the graphical presentation may be considered suitable, under average conditions, for the intended purpose.

Specific data regarding actual total operating costs and manpower requirements for individual components of wastewater treatment plants have been developed on the basis of extensive field investigations at a number of operating wastewater treatment facilities throughout a wide geographical area of the country. Field investigation included on-site examination of facilities in operation, examination of operation and maintenance cost records, and interviews with plant supervisory personnel, the latter to obtain necessary breakdown estimates of employee responsibilities and individual time allocation.

Evaluation of field information is based not only on specific data developed, but also recognizes, where applicable, general operating conditions found at the individual plants investigated. Local conditions recognized include physical condition of the plant, plant load, stated personnel needs, possible misuse of and lack of personnel, and other factors.

PART ONE - CONSTRUCTION COSTS

SECTION I

GENERAL CONSIDERATIONS

Part One of this report is concerned with estimating construction costs and other initial investment costs of wastewater treatment plant components. Relationships of estimated construction costs to appropriate capacity parameters for each of the various major plant components are presented. Estimates of initial investment costs of complete wastewater treatment plants, or additions to existing plants, may be developed on the basis of these relationships.

Actual costs of treatment facilities designed by Black & Veatch have served as the principal basis for establishing the average construction cost relationships presented. Due to the significant changes in the design and costs of wastewater treatment facilities which have occurred over the years, only projects constructed since about 1950 have been considered in this study. Design and construction cost data for 76 separate projects have been studied in detail as a basis for establishing average construction costs of respective wastewater treatment plant components.

Experience data available for certain components, such as raw wastewater pumping stations, sedimentation basins, and trickling filters, which are common and are relatively standard in design, provide an adequate basis for respective construction cost to capacity relationships On the other hand, experience data available for components such as sludge incinerators and centrifuges are so limited or are in such form that respective cost relationships must be based almost entirely upon estimated rather than experience costs. The basis of cost relationships for most components includes some combination of experience and estimated data.

Wastewater treatment projects used as bases of experience data regarding construction cost cover a wide geographic area, and are, therefore, representative of varied construction conditions which may be encountered. In order to make the data comparable, actual costs of projects have been trended to a common cost level. This is accomplished by the use of the national average Water Quality Office - Sewage Treatment Plant (WQO-STP) Cost Index, as of January 1971. The cost index of that date had a value of 150.60.

Estimates of construction costs presented are representative of national average price levels as of January 1971. If the estimating data are to represent costs in a particular area at a different date, they must be adjusted accordingly. The cost adjustment can be based upon the WQO-STP index which permits comparison of price levels at differing locations and dates. The adjustment should be made to reflect price levels expected to prevail throughout the anticipated project construction period.

Experience construction costs require adjustment in certain cases to insure comparability. For example, in the case of raw wastewater pumping stations, some experience data included costs for electrical work, and heating and ventilating, while other data excluded these items. Therefore, it is necessary to develop a "basic" cost relationship, exclusive of electrical, heating and ventilating costs, with subsequent adjustment of the basic curve to obtain a suitable "total" cost curve.

In order that resulting cost to capacity relationships may be as representative of average conditions as possible, experience construction costs have been adjusted to exclude costs of unusual construction requirements such as foundation piling, rock excavation, or dewatering in an effort to compare normal or average condition costs. Costs for these items are not included in total cost curves in this report.

It is recognized that wastewater treatment plant design is in a period of change resulting from developments incorporating features which meet more stringent requirements regarding the quality of plant effluents, and increased system reliability. Estimates of average construction costs presented reflect design experience largely for the period from 1950 through 1968 and may not be fully representative of design for new projects. Where warranted, estimates should be increased accordingly. The magnitude of the possible increase in estimates would vary with the complexity of the specific design under consideration, but may be on the order of 10 per cent.

The determination of parameters to which construction costs of respective plant components may be related is an important consideration in this study. Parameters must be of a nature that are readily available to the estimator on the basis of preliminary design, and must have a logical and reasonable correlation with construction costs.

Estimated costs of engineering, legal, fiscal, and administrative services, land and interest during construction, related to wastewater treatment projects have been developed, and are presented, separately from estimates of construction costs. Total project costs may be estimated by combining estimates of construction with other related costs.

The estimated relationships of construction costs to capacities subsequently presented in this report are based in part upon graphical analysis of both experience and estimated data. It should be recognized, however, that it is impractical to recognize all variations of design occurring among individual projects. Therefore, significant judgment has been exercised in the establishment of curves used to designate cost relationships. The resulting curves represent the investigators' best judgment as to base construction costs to which the costs of special construction conditions are generally additive.

Based upon variations in experience construction costs, it is estimated that costs of individual components for particular situations will often vary as much as 40 per cent from the average costs represented by graphical curves, and in particular cases the variation may be much greater. The variations are due to differences of design, construction site conditions, the economic climate at the time construction bids are taken, and many other factors not readily subject to evaluation on an average basis. The percentage variations of experience costs of projects comprised of several components may be less than indicated for individual components, due to the tendency for composite estimates to vary less than individual components.

While actual costs may vary appreciably from estimated average costs, data presented in this report should be of value, when used with judgment, as basic indicators for preliminary cost estimates. The user should recognize the inherent limitations of such estimates and should develop applicable cost estimates as warranted by local circumstances.

In this report, data for estimating initial investment costs for wastewater treatment facilities are presented in 25 principal parts. Of these, 21 are related to construction costs of specific physical components of plant facilities, and the remaining 4 are additional costs related to the overall investment required.

The principal parts of initial investment cost estimates presented are as follows:

1. Raw Wastewater Pumping
2. Preliminary Treatment
3. Sedimentation
4. Trickling Filters
5. Aeration - Basin Structures
6. Aeration - Diffused Air System
7. Aeration - Mechanical Aerators
8. Recirculation or Intermediate Pumping
9. Chlorination Feed Systems
10. Chlorination Contact Basins
11. Primary Sludge Pumping
12. Sludge Holding Tanks
13. Sludge Digestion
14. Sludge Drying Beds
15. Sludge Lagoons
16. Vacuum Filtration
17. Centrifugation
18. Incineration
19. Administration and Laboratory Facilities
20. Garage and Shop Facilities
21. Yard Work
22. Engineering
23. Land
24. Legal, Fiscal and Administrative
25. Interest During Construction

The estimated construction costs shown for each of the major plant components listed in the first 21 items include all elements of construction cost a contract bidder would normally encounter in completing the specific structure named. Such costs include building materials, labor, equipment, electrical, heating and ventilating, normal excavation and similar items for the particular structure or group of structures described. The item of yard work covers elements of construction cost not within the limits of the structures delineated, such as general grading, piping, electrical work, driveways, fencing, and other items outside of structures.

Estimates of construction costs do not include extraordinary costs related to large amounts of rock excavation, site dewatering, and piling. Such costs cannot reasonably be included in average cost estimates. If such conditions are encountered, the estimator must include an adequate allowance for the extraordinary expense involved.

The last 4 items listed are normally over and above construction contract bid costs, but are valid and necessary parts of total initial investment required to complete a wastewater treatment facility. Provision is made herein for adding these costs to construction costs to derive an estimate of total investment required.

Following the presentation of cost relationships for the 25 components of conventional wastewater treatment plants, a calculation summary form and example application are presented as illustrations of their use.

SECTION II

ESTIMATES OF CONSTRUCTION AND RELATED COSTS

Estimates of construction and other initial investment costs for plant components are delineated in this section of the report.

RAW WASTEWATER PUMPING

The location of wastewater treatment plants often requires that influent raw wastewater be pumped to provide adequate head for gravity flow of the wastewater through the various treatment facilities.

The construction cost of raw wastewater pumping stations may be significantly affected by a number of factors including pumping capacity, site conditions, influent sewer depth, pumping head, provision for growth, degree of station automation, the number of pumps, and architectural considerations. For the purposes of this study, initial firm pumping capacity is the parameter to which construction costs can best be related. Initial firm pumping capacity is defined as the total capacity of the original installation with the largest pumping unit out of service.

Common practice in the design of wastewater pumping stations is to initially provide sufficient firm capacity to meet peak wastewater flows anticipated in the short range future. Station structural design is usually based upon providing ultimate capacity to meet anticipated flows for a longer period, and often incorporates space and piping connections for installation of any additional pumping units which may be required.

Approximate ratios of initial total pumping capacity and ultimate firm capacity to initial firm capacity, based upon analysis of these factors for a number of actual stations are as follows:

Initial Firm Pumping Capacity mgd	Ratio of Initial Total Pumping Capacity and Ultimate Firm Pumping Capacity to Initial Firm Pumping Capacity %
Up to 5	150 - 200
5 to 25	133 - 150
25 to 400	125 - 133

As a means of protecting equipment, where practical, grit removal and screening facilities are located ahead of the raw wastewater pumps. Since screening equipment, either of the bar screen or comminutor type, may be readily constructed in pumping station influent channels, such equipment is normally included in the station design.

Design and construction cost data for 39 raw wastewater pumping stations have been analyzed as a basis of estimating the relationship of construction cost to capacity. Figure 1, Page 34, shows the plotting of basic construction cost against initial firm pumping capacity for these stations. The basic construction cost in this case excludes heating and ventilating, electrical work, rock excavation, site dewatering, and foundation piling. The dashed curve drawn on the figure represents the estimated average basic construction cost. Estimated electrical costs based upon data for 15 stations, and heating and ventilating costs based upon data for 24 stations, have been developed and are included in estimates of total cost represented by the solid curve on Figure 1.

The estimated total construction costs of raw wastewater pumping stations, shown on Figure 1, include the costs of normal earth work, the pumping station structure, pumping equipment, controls, piping within the structure limits, screening facilities, electrical, heating and ventilating, and other auxiliary equipment such as hoists and elevators. Costs of rock excavation, site dewatering, cofferdams and sheet piling are not included in the estimates.

Due to wastewater pumping station location and structure depth requirements, it is expected that either rock or wet conditions may be encountered at some pumping station sites. If rock excavation, dewatering, or piling is required at a particular location, it is essential that the estimator provide for such extraordinary costs. These costs will vary widely depending on local conditions. Costs due to such conditions were incurred at 28 of the 39 pumping stations studied. Based upon data for 14 locations where rock was encountered, the excess cost of excavating rock over the cost of excavating similar earth quantities added an average of about 4 per cent to the total construction cost. Site dewatering, sheet piling, or cofferdams were required for construction of 20 of the 39 pumping stations studied, with the average cost being on the order of 7 per cent of total construction costs. These costs are not included in the estimates in this report.

PRELIMINARY TREATMENT

Preliminary treatment, as used herein, refers to grit removal, screening, and flow measurement. Grit removal and screening are provided principally as a means of protecting subsequent treatment facilities from excessive wear and deposition of grit and large items carried by the raw wastewater. Flow measurement facilities, particularly Parshall flumes, are structually similar to grit and screen channels, and are often included with the preliminary treatment complex.

At plant sites where the influent wastewater must be pumped, screening facilities are normally located in the pumping station influent channels. Estimated pumping station construction costs shown in Figure 1 include the costs of screening equipment.

Costs of preliminary treatment facilities, including only grit removal and flow measurement, exclusive of screening facilities, have been estimated for use in estimating costs of treatment plants with raw wastewater pumping. A second estimated cost relationship for grit removal, flow measurement and screening, has been developed for use in estimating costs of plants without influent pumping.

Maximum flow capacity is a principal factor affecting the construction cost of preliminary treatment facilities and is used as the parameter to which estimated construction costs are related.

Design and construction cost data for 40 preliminary treatment installations have been reviewed as a basis for development of the construction cost to capacity relationship. Sufficient data were available for 8 of these installations to permit determination of respective costs of grit removal and flow measurement facilities, as indicated on Figure 2, Page 35.

Similarly, data available for 10 installations were sufficiently detailed to permit the determination of costs of screening with grit removal and flow measurement facilities. These experience cost data are shown on Figure 3, Page 36.

Estimates of costs of preliminary treatment, based upon incomplete data available for the remaining preliminary treatment installations studied, and upon estimated installations, have been developed to supplement experience cost data, and are also shown on Figures 2 and 3. The estimated cost data, in this instance, have been developed and used principally as a means of extending the data range to the smaller and larger sizes of installations required. For example, in Figure 2, all of the estimates are above the total cost curve. However, they are not permitted to overide the value of experience data but are of value in establishing the shape of the curve and in extending the curve.

Curves shown on Figures 2 and 3, Pages 35 and 36, represent the estimated total average construction costs of preliminary treatment facilities excluding and including screening, respectively. The estimated total costs include costs of flow channels and superstructures, grit handling, screening, comminuting and flow measuring equipment, electrical, heating, ventilating, and auxiliary equipment as required.

SEDIMENTATION

Sedimentation, the most universal of the wastewater treatment plant components, provides the initial step in the separation of the raw wastewater solids and liquid. The reduction of the wastewater flow velocity in basins with relatively large cross-sectional area allows solids with a specific gravity greater than the liquid to settle. At the same time, solids of lesser density form a scum on the basin surface. Collector mechanisms move the concentrated solids to wells for withdrawal and further processing, while the clarified liquid flows over weirs to subsequent treatment.

Primary sedimentation basins are used basically to remove most of the suspended solids from raw wastewater, while intermediate and final basins are used to remove solids produced in secondary treatment processes. While the three types of basins differ somewhat in design, the differences are relatively minor, and construction costs of basins of the same size are similar for each type.

Surface overflow rate and detention time are the factors having the greatest effect upon sedimentation basin sizing, and hence construction costs. Normal liquid depths of 7 to 12 feet, when combined with appropriate overflow rates, will provide the necessary detention time. Since the range of normal liquid depths is relatively small, basin construction costs may be readily related to surface area.

The construction cost of sedimentation basins per unit of surface area generally decreases as the basin size is increased. Circular sludge collection equipment is available for basins up to at least 350 feet in diameter. However, the reduction in construction cost per unit of surface area is slight for basins larger than about 200 feet in diameter, which is considered the maximum size applicable to most installations. Square or rectangular basins may be arranged in large complexes to use common wall construction. Individual square cells using circular sludge collecting equipment normally would not be larger than about 200 feet in length or width. Individual rectangular cells with straight line sludge equipment normally do not exceed about 300 feet in length by 40 feet in width.

It is considered good design practice to provide total required basin surface area in at least two basins or cells which can be operated independently, even though the resulting basins may have less than maximum practicable dimensions. This consideration provides for at least partial sedimentation with one basin, or cell, out of service. At larger treatment plants several basins may be provided to permit greater flexibility in operation.

Design and construction cost data for primary or final sedimentation basins for 62 actual wastewater treatment projects have been studied as the basis for estimates of the relationship of construction cost to basin surface area.

Figure 4, Page 37, shows experience costs plotted against surface area for these projects. Costs of facilities normally located within the structure limits are included, while costs of piping to and from the basin and distribution structures are excluded. Costs of facilities outside the structure are included in yard work. Experience costs are separated into those for single basin installations, and those where two basins were built.

The total cost curve shown on Figure 4 represents estimated average construction costs for sedimentation facilities based upon experience data for both single and multiple basins, the relationship between the two, and recognition of the characteristics of the particular locations represented by the experience data.

Data from Figure 4 is applicable to either primary, intermediate, or final sedimentation facilities. Costs of the basins may be estimated by entering the curve at the surface area requirement for the installation concerned. Estimating costs include all necessary excavation, backfill, concrete, mechanical and electrical equipment, piping and other work related to sedimentation basin construction.

TRICKLING FILTERS

Sizing of trickling filters is normally based on the organic loading per unit of filter volume. Filter rock depth is normally limited to the range of about 6 to 10 feet to assure adequate ventilation of the media. Within this depth range, the hydraulic loading of the filter surface area is usually within acceptable limits.

The cost of filter media, which is directly related to volume, may represent approximately 30 per cent of total trickling filter construction costs. Other costs, such as underdrain costs, are more directly related to filter area but within the normal range of filter depths, may also be related to the filter media volume.

Trickling filter construction cost per unit of media volume decreases as the volume of individual filters is increased within practical limits. However, unit cost reductions are slight for filters larger than about 200 feet in diameter. As stated previously, filter depths are normally limited to a maximum of about 10 feet. Based upon these considerations, the maximum single filter volume would be about 300,000 cubic feet.

Design and construction cost data for 30 trickling filter installations have been reviewed for the development of an estimated relationship of construction costs to filter rock volume. Experience construction costs of the 30 filter installations are plotted against the media volume on Figure 5, Page 38.

Construction costs of trickling filter installations 35, 70, 100, 150 and 200 feet in diameter, respectively, and 6 to 10 feet in depth have been estimated to supplement experience cost data. These estimates are for single and multiple trickling filters. Total filter requirements for new wastewater treatment plants are often divided between two filters so that secondary treatment can continue to some degree if one filter is out of service. The estimated data are used principally to confirm the shape of the curve and to permit extension of estimates to sizes smaller than experience data indicates.

The total cost curve shown on Figure 5 is for the construction of trickling filters under normal conditions, including costs of earthwork, structure, underdrain system, filter media, rotary distributor and other items within the limits of the filter structure. Costs of piping to and from the filter and distribution structures are included in yard work. If significant amounts of rock excavation, dewatering or piling are required, appropriate additions should be made to the estimate.

The curve assumes volume requirements will usually be divided into two filters for total requirements up to about 600,000 cubic feet, and three or more filters for larger volume requirements.

AERATION

The primary use of aeration in wastewater treatment is in the activated sludge secondary treatment process. Other treatment elements using aeration include preaeration, chemical mixing, and flocculation, the latter two uses being largely for agitation purposes. Aeration facilities for each of these processes are similar, and construction cost to capacity relationships developed are applicable for estimating costs of any of these functions.

Since the capacities of aeration basins and equipment are not directly related, separate cost to capacity relationships are developed for these major components.

Basin Structures.

The liquid volume of aeration basins is a parameter which can be readily determined in design and to which construction costs are suitably related.

Design and construction cost data for 7 rectangular and 3 circular actual aeration basin installations have been analyzed as a basis for estimating the relationship of construction cost to volume. Experience construction costs of these basins are plotted against liquid volume on Figure 6, Page 39. Construction costs of rectangular aeration basin complexes with total volumes of 22,000, 105,000, 670,000 and 3,700,000 cubic feet and of multiple circular basins with individual volumes of 24,000 and 265,000 cubic feet, respectively, have been estimated to supplement experience cost data and are also shown on Figure 6. Based upon the available data, construction costs appear to be somewhat higher for rectangular basins than for circular basins, but for purposes of this report a single estimating curve is used.

The estimated relationship of construction costs to the liquid volume of aeration basins is shown by the curve of Figure 6. The indicated costs include only the normal structure related costs, and exclude costs of aeration equipment, air piping and diffusers.

Diffused Air System.

Construction costs of air blowers, piping and diffusers, and the blower building are generally related to the air supply capacity. The quantity of air required depends upon a number of factors, principally the wastewater characteristics, and treatment process used.

The design of air supply installations normally provides for initial firm blower capacity sufficient to meet requirements anticipated in the short range future. Firm capacity is the capacity remaining with the largest blower unit out of service. Air requirements anticipated in the longer range future are often considered by allowing space and piping connections so that additional blower units may be readily installed. The firm blower capacity initially installed is the parameter to which initial construction costs are most related.

Approximate ratios of initial total blower capacity and ultimate firm capacity to initial firm capacity, based upon analysis of these factors for a number of actual stations, are as follows:

Initial Firm Blower Capacity 1000 cfm	Ratio of Initial Total Blower Capacity and Ultimate Firm Blower Capacity to Initial Firm Blower Capacity %
Up to 30	150 - 200
30 to 100	130 - 150
Over 100	120 - 130

Construction cost and design data for 5 actual diffused air system building and equipment installations have been studied as a basis for developing the construction cost to capacity relationship.

To supplement experience data, construction costs of aeration building and equipment installations with firm capacities of 850, 4,000, 26,000 and 196,000 cubic feet per minute have been estimated. The experience and estimated construction costs are plotted against the initial firm blower capacity on Figure 7, Page 40. The estimated cost data have been developed and used in this instance principally as a means of indicating the general shape of the cost curve and to extend the data range to the larger sizes required. The curve shown represents the estimated average construction costs of diffused air systems, including a building housing the blowers, blowers and associated electrical work, air piping within the blower building and to the aeration basins, and the air diffusers in the aeration basins.

Mechanical Aerators.

Mechanical aerators are used in lieu of diffused air systems in some activated sludge secondary treatment installations, and include vertical draft tube, paddle, or disc, and spray aerators. In the United States, application of mechanical aeration for wastewater treatment is limited principally to vertical draft tubes, and estimating data presented herein are based upon this type of equipment.

Construction costs of vertical draft tube aerator installations are most related to the total horsepower requirements. Total power requirements of particular installations depend upon the quantity and strength of wastewater to be treated and the degree of BOD removal desired. The total horsepower requirements can be met by use of multiple aerator units which are available in sizes up to at least 200 horsepower each. Good design practice dictates that total requirements be divided between two or more units so that at least partial treatment can be accomplished at all times. In addition, a complete spare unit is often provided for the replacement of units requiring significant maintenance.

The relationship of mechanical aeration equipment costs to total installed horsepower shown on Figure 8, Page 41, is based entirely upon estimated data. The position of the estimating curve in Figure 8 takes into account the number of installed units likely to be required at a typical installation and is only indirectly related to the data points shown. The estimates include costs of the aerator motor, gearbox, impeller, draft tube, supporting structure and applicable electrical work. An allowance for a spare aerator unit is also provided in the cost estimates for larger installations.

RECIRCULATION OR INTERMEDIATE PUMPING

The terrain and the design of particular wastewater treatment plants may require that, after partial treatment, the wastewater must be pumped to subsequent treatment processes, or to the receiving body of water. Pumping may also be necessary for trickling filter, activated sludge, or other recirculation service within the plant. Stations serving these functions are usually less costly than raw wastewater pumping staions, since they handle relatively clear water and do not require deep wet wells.

Factors affecting intermediate pumping station construction costs are similar to those applying to raw wastewater pumping stations, with initial firm pumping capacity as the capacity parameter to which construction costs can most suitably be related. The ratios of initial total, and ultimate firm, pumping capacities to initial firm pumping capacities for raw wastewater pumping stations are also applicable to recirculation or intermediate pumping stations.

Figure 9, Page 42, shows the experience basic construction cost of 10 actual recirculation pumping stations plotted against initial firm capacity. Basic costs shown on the figure exclude electrical, heating and ventilating costs. The estimated average basic construction costs, based upon the available data, is shown by a dashed curve. The shape and slope of the curve for larger capacities for which no experience data were available has been guided by the similar curve for raw wastewater pumping.

Estimates of electrical, heating and ventilating costs have been developed and are included in estimates of total construction costs represented by the solid curve on Figure 9. The total costs include normal earthwork, structure, equipment, controls and other elements essential to a complete pumping station.

CHLORINATION

Chlorine is used for a number of functions in wastewater treatment with disinfection of the plant effluent wastewater prior to discharge to the receiving waters being the principal use. Other uses include the control of septicity, odors, trickling filter ponding, and activated sludge bulking. While the chlorine dosages and points of application vary among respective chlorination functions, chlorine feeding, handling and storage facilities are similar for given daily requirements. However, adequate chlorine contact periods may be provided in other treatment facilities, such as primary basins or plant effluent conduits, or in contact basins provided for that function only.

Feed Systems.

Construction costs of chlorination equipment, the chlorine feed building, and chlorine storage building, are related to average and peak chlorine requirements. While chlorination equipment, and space therefor, is sized on the basis of peak chlorine requirements, the capacity range of most chlorination equipment is quite large, and the variation of equipment cost with capacity is relatively small and may be related to average chlorine use. Space requirements for storage of chlorine inventories, a significant portion of the cost of chlorination installations, are based upon average chlorine use. Therefore, the anticipated average chlorine use at design flow conditions is the parameter to which construction costs are most related.

Because chlorine installations are often incorporated with other facilities, the actual construction cost data available for use in these studies is quite limited. Costs of 5 installations for which experience data are available are plotted against respective average chlorine use on Figure 10, Page 43. As a supplement to the limited experience cost data, construction costs of other estimated chlorination installations have been prepared and are also shown on Figure 10. The estimated cost data have been developed and used principally as a means of extending the data range to the smaller and larger sizes of installations required. The estimated data are not permitted to override the value of experience data but are of value in establishing the shape and extending the curve. Estimated average construction costs of the chlorination building and equipment, based upon the available data is indicated by the curve on Figure 10.

Construction cost estimates shown on Figure 10 include the costs of chlorine feeding and handling equipment, scales, evaporators where required, structures housing the equipment, and chlorine storage space.

Cost estimates presented are based upon the purchase of chlorine in 150 or 2,000 pound cylinders. For chlorine uses exceeding about 2,000 pounds per day, it may be advantageous to purchase chlorine in tank cars. However, the availability and costs of rail facilities are unique to respective individual locations and development of average cost estimates is impractical.

Contact Basins.

A contact time of not less than 15 minutes at maximum flow rates is required for chlorination to be an effective disinfectant. Plants with long, low velocity effluent lines may have ample contact time provided in the effluent line, while plants with only short outfalls may require separate contact basins.

The determination of contact basin volume required is based upon provision of the required detention time, and, since construction costs are most related to basin volume, this parameter is the most appropriate basis of the construction cost to capacity relationship.

Figure 11, Page 44, shows experience costs of 6 contact basin installations and costs of 3 estimated basins plotted against the respective liquid volumes of the basins. Estimated data points are used solely as a guide to the shape of the curve and its extension beyond the limits of experience data. Estimated data points are not given as much weight in curve location as experience data. Estimates of average contact basin construction costs are represented by the total cost curve shown on Figure 11. In developing the estimated average cost curve, the values shown in Figure 6 for aeration basin structures have been recognized due to the similar natures of the structures.

Figure 11 estimates include allowances for costs of the basin structure, normal earthwork, and baffles to prevent short circuit flows. The estimates do not include costs of sludge collection mechanisms which may be required in basins receiving primary treatment effluent.

PRIMARY SLUDGE PUMPING

Sludge pumping stations are normally located adjacent to sedimentation basins with the pumps taking suction from sludge hoppers in the basin bottoms. Station substructures frequently have at least one wall in common with the sedimentation basin.

As in the case of the raw wastewater and intermediate pumping stations, firm pumping capacity is the parameter to which sludge pumping station construction costs are most related. A common design includes a sludge pumping station for each two sedimentation basins. Each station may be equipped with three pumps, one sludge pump for each basin, and a single scum pump for both basins. The three pumps are identical and piping is so arranged that any pump can serve the normal function of either of the other two pumps. Since sludge and scum withdrawals are normally not continuous, this pump arrangement, by using individual pumps for alternate service, provides required capacity even if one pump is inoperative. With three pumps of equal capacity, total installed capacity is 150 per cent of firm capacity. While space for future pump installations is sometimes provided, this practice is less common in sludge pumping stations than in raw sewage pumping stations.

Construction cost and design data for 11 actual sludge pumping stations have been studied as a basis for developing the estimated construction cost to capacity relationship. Costs of other stations have been estimated to supplement experience data. The experience and estimated basic construction costs are plotted against initial firm pumping capacity on Figure 12, Page 45. Costs of installations having two and three separate stations, also shown in the figure, are based upon estimated station costs. All experience cost data are for installations with single sludge pumping stations. Basic construction costs plotted on Figure 12 include the costs of normal earthwork, station structures, piping and pumping equipment but exclude electrical, heating and ventilating costs.

The estimated basic cost, represented by the dashed curve on Figure 12, is based upon the plotted data taking into account the number of installed units likely to be required at a typical installation. Estimates of electrical, heating and ventilating costs have been developed and are included in the estimated total cost represented by the solid curve on Figure 12.

SLUDGE HOLDING TANKS

Sludge holding tanks are often provided where raw sludge is to be filtered, or following digestion, and prior to final sludge disposal. The use of holding tanks serves to dampen fluctuation in the quantity and quality of sludge flow to the filters, or to other disposal facilities. Holding tanks may also be used to concentrate sludge by decanting liquids after stratification of sludge in the tank.

Construction costs are more related to the volume of the tank than to other parameters which may be considered in the determination of the tank size.

Cost and design data for 10 actual holding tanks have been analyzed as the basis for the development of construction cost to capacity relationships. Costs of these installations are plotted against respective tank capacities on Figure 13, Page 46. The designs of the actual tanks are quite varied, ranging from simple open tanks with no equipment and a minimum of piping to tanks with floating covers and mechanical or aerated mixing equipment, or with mechanical sludge collecting equipment similar to that used in sedimentation basins. These design variations are considered typical of requirements for particular applications, and normalization of costs to reflect a standard design has not been attempted.

Construction costs of 4 additional sludge holding tanks have been estimated as supplements to the available experience cost data and are also shown on Figure 13. These costs are based upon a simple tank design, and are considered to be about minimum for the respective tank sizes.

The curve shown on Figure 13 represents the estimated average relationship of construction costs to sludge holding tank volume. The curve is based principally upon the experience data, with the slope influenced by estimated data. Figure 13 estimates are based upon average site conditions.

SLUDGE DIGESTION

Digestion is the biological process of reducing organic matter present in raw sludge to an inert state. The reduction may be by either aerobic or anaerobic processes, the latter being the most frequently used for wastewater treatment plants and the one to which cost estimates presented herein are applicable.

Digestion tank volume requirements, to which construction costs are related, depend upon a number of factors including the quantity and characteristics of sludge, digester operating temperature, digested sludge storage requirements, and the degree of digestion desired. A control building enclosing sludge circulating, heating and control facilities normally has walls in common with adjacent digesters. A frequent configuration includes a control building located between a pair of digesters.

Construction cost and design data for 32 digester and control building installations have been analyzed as a basis for estimating the construction cost to volume relationship. Construction costs of these installations are plotted against respective sludge volumes on Figure 14, Page 47. The volumes used are computed on the basis of the sidewater depth only and exclude the freeboard and conical bottom volumes.

Construction costs have been estimated for digester installations utilizing diameters of 50, 65, 85 and 100 feet, respectively, to supplement experience cost data. The estimated costs of installations consisting of one digester with control building, and two digesters with control building, are shown on Figure 14. The curve shown on Figure 14 is based upon the available data and represents estimated normal construction costs of digesters and control buildings.

The construction cost per unit of digester volume decreases as total volume increases up to the maximum volume of two digesters with a control building. The largest volume practical in such an installation is about 400,000 cubic feet, based upon two digesters with diameters of 100 feet and sidewater depths of about 25 feet. Construction cost estimates shown on Figure 14 for volumes larger than 400,000 cubic feet are based on the assumption that multiples of this arrangement would be utilized without further reduction of cost per unit of digester volume.

The estimates of costs shown on Figure 14 include allowances for normal digester and control building structures, sludge heating, circulating and control equipment, and piping within the limits of the structures. Cost of piping to and from the digesters is not included in these estimates but is included in yard work.

SLUDGE DRYING BEDS

The drying of sludge on open sand beds is a frequently used method of dewatering sludge, particularly at small plants. The use of drying beds at very large plants is often impractical because of the large land area required.

Construction costs of drying beds are most related to surface area requirements which depend upon the quantity and quality of sludge to be dewatered, local climatological conditions, and whether or not beds will be covered.

As a basis for estimating the construction cost to surface area relationship, construction cost and design data for 22 actual drying bed installations have been reviewed. Construction costs of those beds, all of which are uncovered, are shown on Figure 15, Page 48. Construction costs of 4 estimated uncovered drying bed installations have been developed, and are also shown on the figure.

Estimated average construction costs of open sludge drying beds are shown by the total cost curve on Figure 15. The estimates of costs, based upon available data, include the costs of normal excavation, piping for sludge distribution, sand and gravel drainage beds and underdrain collection piping. The estimates do not include covering structures.

SLUDGE LAGOONS

Sludge lagoons may be used for storage or drying of wastewater sludge, usually following digestion.

Lagoons are designed with capacity to store sludge accumulations for 3 to 5 years, from the time the sludge is placed until it is sufficiently concentrated to permit removal, by mechanical methods, for final disposal. Depths of storage lagoons range from 5 to 10 or more feet. Since drying lagoons are designed to permit removal of sludge cake at more frequent intervals of 3 to 5 months, sludge depths in such lagoons are limited to about 18 inches.

Construction costs of sludge lagoons vary both with the lagoon volume and surface area but, because of the significant depth range, are more directly related to volume.

The estimated relationship of construction cost to the holding volume of sludge lagoons, shown on Figure 16, Page 49, is based upon estimated costs of lagoons with surface areas of 0.5, 4, 20, and 80 acres with sludge depths of 1.5 and 10 feet, respectively. The estimated construction costs include allowances for normal excavation, dike construction, and sludge distribution piping.

VACUUM FILTRATION

The use of vacuum filters for dewatering sludge has increased rapidly in recent years, particularly for medium and larger sized treatment plants where the space requirements for drying beds made the beds impractical.

Construction costs of vacuum filters and associated equipment and structures are most related to the filter surface area. Filter surface area requirements are in turn related to the type, quantity and quality of sludge to be dewatered, sludge conditioning processes used, and average hours of filter operation.

As a basis for estimating the relationship of construction cost to filter surface area, cost and design data for 15 actual vacuum filter installations have been analyzed. Construction costs of these installations are related to respective filter surface areas on Figure 17, Page 50. The indicated basic construction costs are based upon normal construction conditions exclusive of electrical, space heating, and ventilating costs. The estimated basic costs are represented by the dashed curve shown on Figure 17. Estimated total construction costs include an allowance of 20 per cent for electrical, space heating and ventilating costs, and are indicated by the solid total cost curve. Figure 17 estimates include the normal costs of the vacuum filters, auxilary equipment, piping and structures.

CENTRIFUGATION

The use of centrifuges for dewatering wastewater sludge has increased significantly in recent years as the use of sludge drying beds has declined. While centrifuges are particularly applicable for use at plants too small to justify initial investment and operating costs of vacuum filtration, they also are applicable for use at some larger plants.

A number of variables, including sludge feed rate, solids characteristics, temperature, and conditioning processes, influence the selection of centrifugation equipment applicable to particular treatment plants. Of these, sludge feed rate is the single parameter having the greatest influence on the equipment selection, and hence on construction costs.

The estimated relationship of centrifugation construction costs to firm capacity is shown on Figure 18, Page 51. Firm capacity, as used here, is the total installed capacity with one centrifuge inoperative. The Figure 18 total cost curve is based entirely upon costs for estimated centrifuge installations. The cost estimates include allowances for centrifugation equipment, sludge pumps and piping, sludge cake conveyors, equipment hoists, electrical facilities and an enclosing structure.

INCINERATION

The disposal of wastewater sludge by incineration is of increasing significance as the availability of land for drying beds and landfills decreases. The problem of limited land available for these uses is compounded as the quantity of sludge requiring disposal increases.

Several parameters, including quantity of sludge to be incinerated, the anticipated schedule of incinerator operation, the moisture, volatile, and inert contents of the sludge, and the heat value of the sludge are considered in the determination of incinerator size. With the exception of quantity and operation schedule, the ranges of these parameters normally encountered in wastewater sludge are relatively limited and can be represented by average values within the accuracy needed for this study. Therefore, incinerator capacity requirements, which may be estimated for particular installations on the basis of the quantity of dry solids in pounds per hour, is the parameter to which construction costs may be most suitably related.

The estimated relationship of multiple hearth incinerator costs to respective capacities is shown on Figure 19, Page 52. The estimated average construction costs, represented by the total cost curve, are based partially upon limited experience data available, but principally upon estimated installations, as indicated by the plotted data. The total cost curve is based upon the assumption that a single incinerator unit would suffice for the smaller capacity installations, while for the larger installations it is anticipated that total capacity requirements would be divided between two or more units.

Figure 19 estimates include allowances for normal costs of multiple hearth furnaces with auxiliary equipment and an enclosing structure. Auxiliary equipment included consists of gas scrubber and exhaust, ash handling, fuel systems, instrumentation, piping, and electrical facilities.

If incineration processes of types other than multiple hearth are considered, the estimator must provide for appropriate adjustment in construction cost estimates.

ADMINISTRATION AND LABORATORY FACILITIES

The effective operation and control of wastewater treatment plants requires space and facilities for administrative functions such as personnel supervision, records keeping, correspondence, a reception area for plant visitors, and a well equipped laboratory for the determination of chemical, biological and other controls of treatment processes. Other space requirements include employee rooms, restrooms, and shower and locker areas. In general, space for administration, laboratory, and service functions tends to vary with average day plant capacity. However, treatment complexity, the degree to which administrative functions are located on the plant site, and other factors, also significantly affect the amount of space provided at particular treatment plants.

Administration and laboratory facilities may be provided in completely separate structures, or may be incorporated within structures serving other functions. The latter arrangement is the most common at plants in the smaller capacity range, while either arrangement may be found at the larger plants.

The estimated average construction costs of administration and laboratory facilities for respective plant capacities are shown on Figure 20, Page 53. The indicated construction cost to capacity relationship based upon costs of estimated facilities. The cost estimates include allowances for the normal costs of required facilities.

GARAGE AND SHOP FACILITIES

Garage and shop facilities range from limited space and tools for minor repair work at small plants to substantial facilities incorporating general repair shops and machine shops at the larger plants. The extent of facilities to be provided at particular plants is dependent upon the availability of nearby commercial or municipal garages and machine shops, plant characteristics, and the number of vehicles to be maintained by plant personnel, as well as plant capacity.

The estimated relationship of garage and shop construction costs to plant average day capacity is shown on Figure 21, Page 54. The costs are based upon estimated installations. Construction cost estimates include costs of structures, equipment and tools, and appurtenant facilities.

YARD WORK

Construction cost estimates presented for individual functional components of wastewater treatment plants are based upon the costs of facilities within the structural confines of the respective components. The total costs of treatment plants also include costs of general site clearing and grading, inter-component piping, valves, overhead and underground electrical wiring, cable, lighting, control structures, manholes, tunnels and conduits, parking, sidewalk and road paving, site landscaping, fencing, and other items outside the structural confines of particular individual plant components. The costs for these items, considered as a group, are commonly referred to as yard work.

Based upon data available for 19 new wastewater treatment plant construction projects, yard work costs range from about 9 to 18 per cent of other construction costs, with the average being about 14 per cent. The available data do not indicate significant variation, with plant capacity, of yard work costs as a percentage of other construction costs.

ENGINEERING

Engineering for wastewater treatment plant projects consists of the two elements of basic services and special services. Basic services include preliminary design reports, detailed design, and certain office and field engineering services during construction of projects. Special services include comprehensive improvement studies, resident engineering, soils investigations, land surveys, preparation of applications for government grants, operation and maintenance manuals, and other miscellaneous services.

The American Society of Civil Engineers (ASCE) has published curves, designated A and B, showing median compensation for basic engineering services of varying complexity. These curves are periodically reviewed and are subject to revision from time to time. The ASCE Curve A has been used in developing estimates of basic engineering services costs.

Average costs of special engineering services are included with costs of basic services in the estimates of total engineering costs indicated by the total cost curve on Figure 22, Page 55.

LAND

Due to continuing urbanization, the cost of land available for wastewater treatment plant sites has increased substantially in recent years, and can be a significant part of the initial plant cost.

The area required for the plant site depends upon plant capacity, type of treatment, treatment components, site topography and requirements for anticipated plant expansions. The area of land actually purchased may also be influenced by the size of tracts available at the selected plant location.

The area of land required for 17 actual treatment plants is plotted against respective average day plant capacities on Figure 23, Page 56. The indicated actual areas are considered minimum and do not include space for plant expansion, or excess unused space, because of site topography. The dashed curve drawn on the figure represents estimated average minimum land requirements. It is estimated that actual land acquisitions may amount to twice the minimum requirements as indicated by the solid curve shown on Figure 23.

Since land costs may vary from a few hundred dollars per acre in essentially rural areas to several thousand dollars per acre in urban areas, average land costs have not been estimated. Total land cost estimates may be derived on the basis of Figure 23 area requirements and land costs applicable to particular locations.

Estimates of land requirements shown on Figure 23 are applicable to treatment plants employing primary and trickling filter, or primary and activated sludge treatment processes, and usual sludge disposal methods. The indicated areas would not be adequate for sludge drying beds or sludge lagoons at plants with capacities in the larger size ranges.

LEGAL, FISCAL AND ADMINISTRATIVE COSTS

Costs of legal and fiscal services, and of owner administration related to planning and construction of wastewater treatment facilities can be substantial. Legal documents must be prepared and the legality of bonds must be certified by qualified bond attorneys. The costs of legal and fiscal consulting services are related, to some degree, to the total amount of debt financing, and hence to total construction, engineering, and land costs. Legal assistance may also be required in other areas such as the preparation of construction contracts and in the acquisition of land.

Even though consultants are used, the administration of the financing, design, and construction of wastewater treatment plants requires substantial time on the part of owner personnel. These items of cost may also be related to the project size as reflected by the total cost.

Total costs of legal, fiscal, and administrative services may be expected to vary widely from one situation to another. Average costs may range from about 3.5 per cent of the costs of small projects to about 0.2 per cent of the costs of larger projects. Figure 24, Page 57, shows estimated average legal, fiscal and administrative costs as related to total construction, engineering, and land costs.

INTEREST DURING CONSTRUCTION

As used herein, interest during construction is the interest cost accrued on funds from the time payment is made to the contractor to the end of the construction period. Interest during construction is a real cost, whether a project is financed through the issuance of debt securities, from accrued earnings, or from other sources. It may be assumed that the interest rate paid on borrowed funds is a valid measure of this cost.

Municipalities frequently finance the construction of major wastewater treatment projects from the sale of bonds prior to the start of construction. Bond funds are then normally invested in short term securities until needed for payments to the contractor, with interest income approximately offsetting interest expense. Hence, the expense for interest during construction may not begin until the actual payment is made to the contractor.

The owner's cost of interest during construction depends upon current interest rates, the length of the construction period, the pattern of payments to the contractor, and the total project costs.

An analysis of monthly payments to contractors for 8 wastewater treatment projects indicates that, while there is considerable variation in the size of monthly payments, the average period over which interest is accrued amounts to one-half the total construction period. Similarly, data for 62 projects indicates that the average total construction period varies with the total cost as shown in the following tabulation.

Total Construction Cost	Estimated Total Period of Construction
$1,000	months
100	6
500	15
1,000	18
5,000	26
10,000	30
50,000	38

The estimated average cost of interest during construction is related to total other project costs on Figure 25, Page 58, for annual rates of interest of 4, 6, and 8 per cent, respectively. Cost estimates are based upon construction periods shown and an average period of interest equal to one-half the construction period. The estimated interest costs may range from about one per cent of small project costs, to about 12 per cent of the costs of large projects.

SECTION III

APPLICATION OF INITIAL INVESTMENT COST ESTIMATING DATA

Table 1, Page 32, presents a form prepared for the purpose of estimating initial investment costs in any particular instance. It is assumed that the estimator has determined from preliminary design the required capacity of plant components and, based upon this premise, the total initial investment cost may be estimated.

Table 1-A, Page 33, illustrates the use of the estimated construction cost data developed in this report for estimating total initial investment costs. The example is based upon a hypothetical wastewater treatment plant of the activated sludge type with an average design capacity of 10 million gallons per day. The example plant provides for vacuum filtration and incineration of sludge.

The sizes and capacities of individual plant components shown for the example are representative of average conditions which may be encountered for the assumed plant. However, since variations in the relative sizes of respective components may be significant, due to differences of wastewater strengths and the overall plant design, the total cost indicated in the example may not be representative for any particular 10 mgd activated sludge plant.

The limitations of cost estimates based upon average conditions are again emphasized. Construction cost data presented herein are applicable as a basis of preliminary estimates for planning requirements and methods, and for general comparative studies of costs of alternative wastewater treatment methods. These data may also be applicable for use by various levels of governmental agencies in estimating the total costs of wastewate treatment facilities required to provide desired levels of treatment for all wastewater effluents in an entire area, state, region or watershed.

Estimates of average construction costs presented reflect design experienc largely for the period from 1950 through 1968 and may not be fully representative of design for new projects. Where warranted, estimates should be increased accordingly.

The data, unadjusted for particular local conditions, cannot be used for specific plant initial cost estimates. If used unadjusted for special local conditions, costs would tend to be understated. This cost estimate source does not supplant the need for individual engineering studies of project costs.

TABLE 1

ESTIMATED INITIAL INVESTMENT COST

Project ________________________; Computed By ___________; Date ___________

Cost Component		Component Parameter	Cost Estimate Reference Figure No.	Cost Estimate Cost $
Raw Wastewater Pumping	________	mgd initial firm pumping capacity	1	____________
Preliminary Treatment - Without Screening	________	mgd maximum capacity	2	____________
Preliminary Treatment - With Screening	________	mgd maximum capacity	3	____________
Sedimentation - Primary	________	1000 square feet surface area	4	____________
Trickling Filters	________	1000 cubic feet filter media volume	5	____________
Aeration-Basin Structures	________	1000 cubic feet liquid volume	6	____________
Aeration-Diffused Air System	________	1000 cfm initial firm blower capacity	7	____________
Aeration-Mechanical Aerators	________	horsepower total installed capacity	8	____________
Sedimentation-Secondary	________	1000 square feet surface area	4	____________
Recirculation or Intermediate Pumping	________	mgd initial firm pumping capacity	9	____________
Chlorination - Feed Systems	________	pounds per day average chlorine use at design flow	10	____________
Chlorination - Contact Basins	________	1000 cubic feet liquid volume	11	____________
Primary Sludge Pumping	________	gpm initial firm pumping capacity	12	____________
Sludge Holding Tanks	________	1000 cubic feet sludge volume	13	____________
Sludge Digestion	________	1000 cubic feet sludge volume	14	____________
Sludge Drying Beds	________	1000 square feet surface area	15	____________
Sludge Lagoons	________	1000 cubic feet sludge volume	16	____________
Vacuum Filtration	________	square feet filter surface area	17	____________
Centrifugation	________	gpm firm capacity	18	____________
Incineration	________	pounds per hour of dry solids incineration capacity	19	____________
Administration and Laboratory Facilities	________	mgd plant average day capacity	20	____________
Garage and Shop Facilities	________	mgd plant average day capacity	21	____________
________________________	________________________		___	____________
________________________	________________________		___	____________
________________________	________________________		___	____________
________________________	________________________		___	____________
________________________	________________________		___	____________
Subtotal			Subtotal	____________
Yardwork	14% of Subtotal			____________
Total Estimated Construction Cost at January, 1971 Cost Level			Total	____________
Trended Total Estimated Construction Cost	________	% Trend Factor (See note below)	Total	____________
Engineering			22	____________
Land	________	acres at $________ per acre	23	____________
Subtotal-Construction, Engineering & Land			Subtotal	____________
Legal, Fiscal, & Administrative			24	____________
Subtotal All Above			Subtotal	____________
Interest During Construction	(At ______% interest)		25	____________
Total Initial Investment Cost			Total	____________

Note:

$$\text{Trend Factor} = \frac{\text{Local WQO-STP Cost Index representative of the construction period}}{\text{National Average WQO-STP Cost Index as of January, 1971}} = \frac{\_\_\_\_\_\_}{150.60} = \_\_\_\_\_\_\%$$

TABLE 1-A

ESTIMATED INITIAL INVESTMENT COST

Project Newton, Nebraska ; Computed By RWB ; Date Sept. 1971

Cost Component		Component Parameter	Cost Estimate Reference Figure No.	Cost Estimate Cost $
Raw Wastewater Pumping	20	mgd **initial firm pumping capacity**	1	450,000
Preliminary Treatment - Without Screening	20	**mgd maximum** capacity	2	82,000
Preliminary Treatment - With Screening		mgd maximum capacity	3	
Sedimentation - Primary	17	**1000 square** feet surface area	4	210,000
Trickling Filters		1000 cubic feet filter media volume	5	
Aeration-Basin Structures	222	1000 cubic feet liquid volume	6	220,000
Aeration-Diffused Air System	14	1000 cfm initial firm blower capacity	7	390,000
Aeration-Mechanical Aerators		**horsepower total installed** capacity	8	
Sedimentation-Secondary	20	**1000 square feet surface area**	4	245,000
Recirculation or Intermediate Pumping	10	mgd initial firm pumping capacity	9	120,000
Chlorination - Feed Systems	850	**pounds per day average** chlorine **use at design** flow	10	62,000
Chlorination - Contact Basins	28	1000 cubic feet liquid volume	11	48,000
Primary Sludge Pumping	190	gpm initial firm pumping capacity	12	55,000
Sludge Holding Tanks	30	1000 cubic feet sludge volume	13	79,000
Sludge Digestion		1000 cubic feet sludge volume	14	
Sludge Drying Beds		1000 square feet surface area	15	
Sludge Lagoons		1000 **cubic feet sludge volume**	16	
Vacuum Filtration	750	square feet filter surface area	17	515,000
Centrifugation		gpm firm capacity	18	
Incineration	3,100	**pounds per hour of dry solids** incineration capacity	19	1,300,000
Administration and Laboratory Facilities	10	**mgd plant average day** capacity	20	110,000
Garage and Shop Facilities	10	mgd **plant average day** capacity	21	33,000
Subtotal			Subtotal	3,919,000
Yardwork		14% of Subtotal		549,000
Total Estimated Construction Cost at January, 1971 Cost Level			Total	4,468,000
Trended Total Estimated Construction Cost	122.1	% Trend Factor (See note below)	Total	5,455,000
Engineering			22	440,000
Land	20	acres at $ 1,000 per acre	23	20,000
Subtotal-Construction, Engineering & Land			Subtotal	5,915,000
Legal, Fiscal, & Administrative			24	38,000
Subtotal All Above			Subtotal	5,953,000
Interest During Construction		(At 6 % interest)	25	410,000
Total Initial Investment Cost			Total	6,363,000

Note:

$$\text{Trend Factor} = \frac{\text{Local WQO-STP Cost Index representative of the construction period}}{\text{National Average WQO-STP Cost Index as of January, 1971}} = \frac{183.90}{150.60} = 122.1\%$$

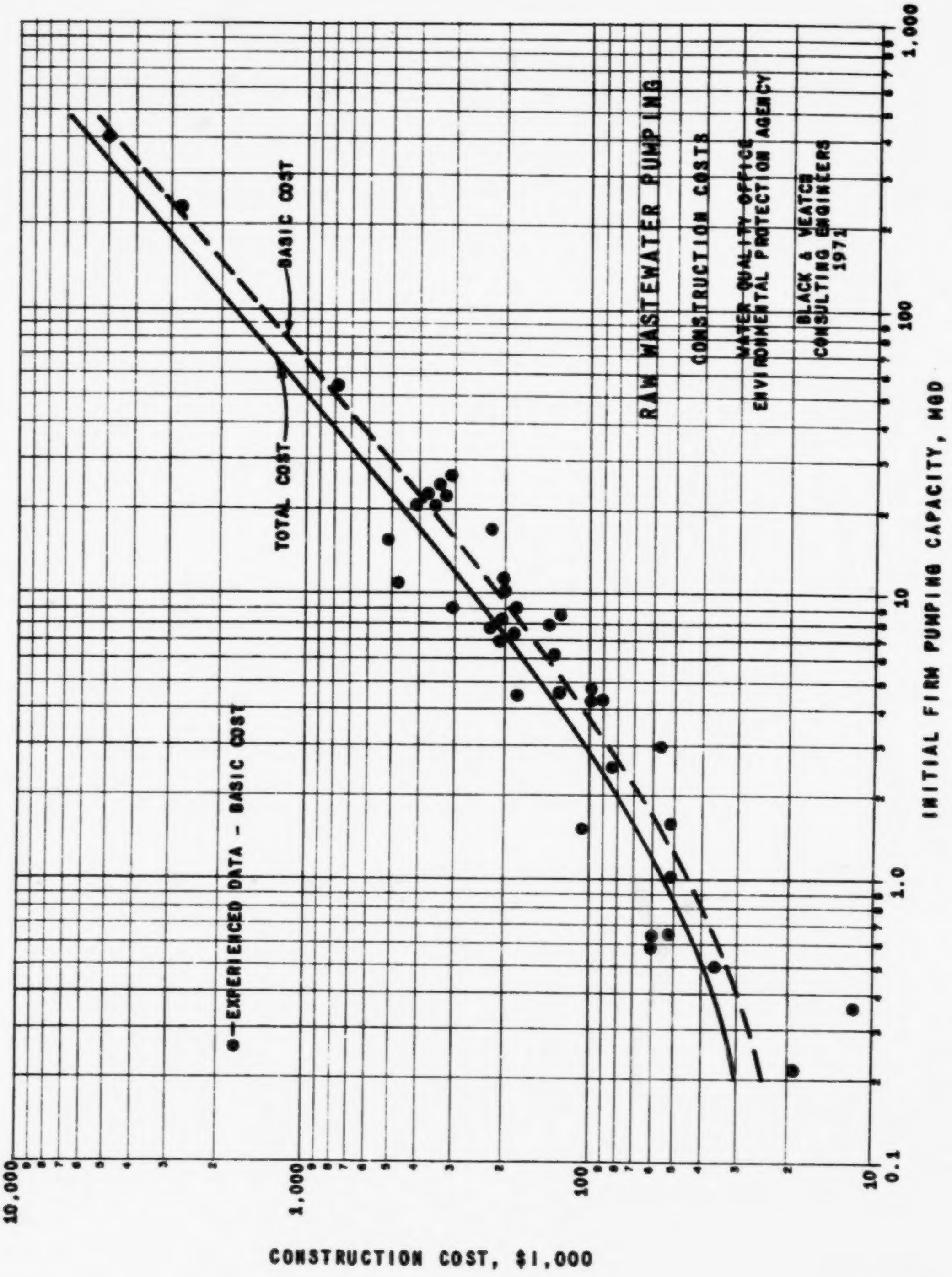

RAW WASTEWATER PUMPING
CONSTRUCTION COSTS
WATER QUALITY OFFICE
ENVIRONMENTAL PROTECTION AGENCY
BLACK & VEATCH
CONSULTING ENGINEERS
1971
BASIC COST
TOTAL COST
●—EXPERIENCED DATA - BASIC COST
INITIAL FIRM PUMPING CAPACITY, MGD
0.1
1.0
10
100
1,000
CONSTRUCTION COST, $1,000
10
100
1,000
10,000

FIGURE I

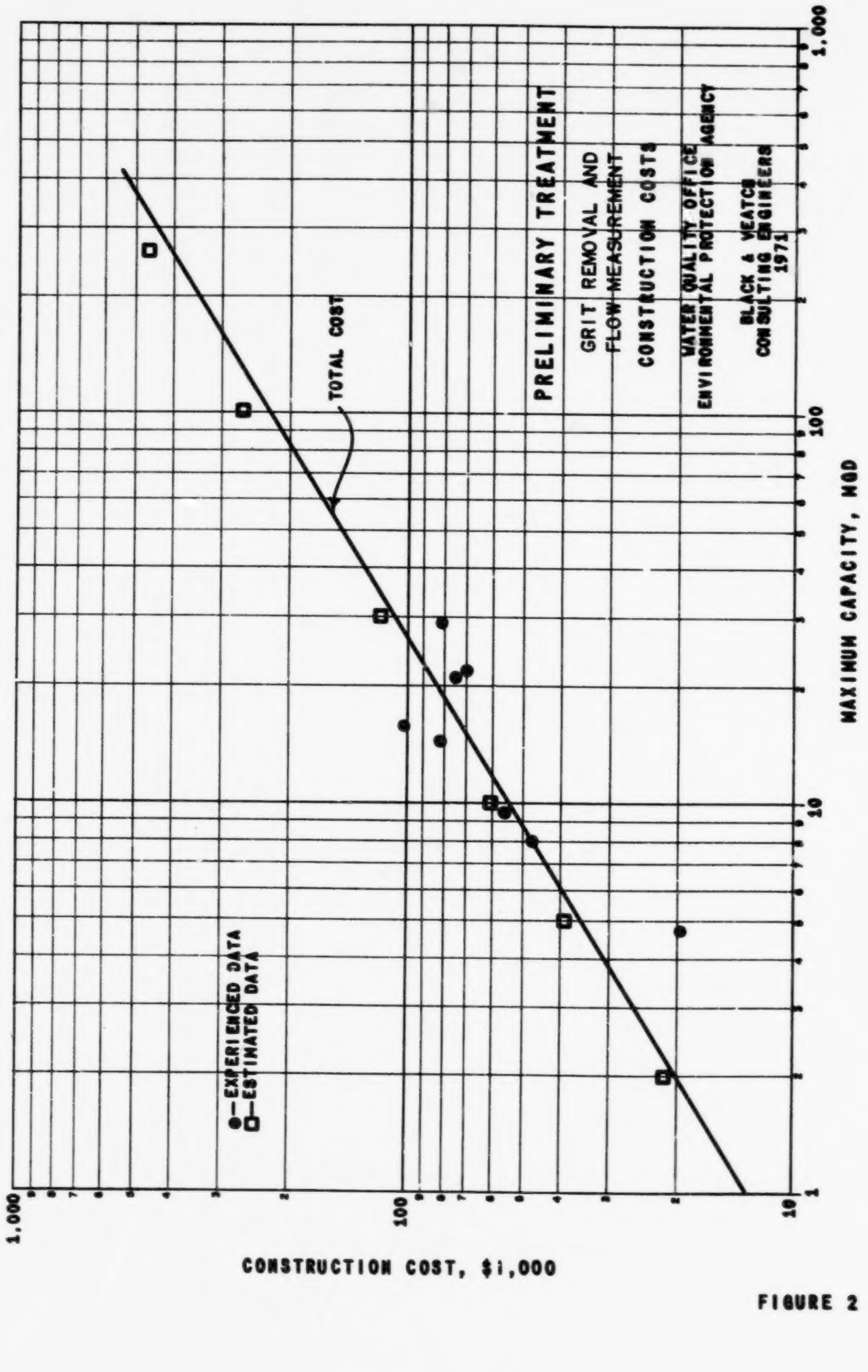

PRELIMINARY TREATMENT
GRIT REMOVAL AND
FLOW MEASUREMENT
CONSTRUCTION COSTS
WATER QUALITY OFFICE
ENVIRONMENTAL PROTECTION AGENCY
BLACK & VEATCH
CONSULTING ENGINEERS
1971
TOTAL COST
●—EXPERIENCED DATA
□—ESTIMATED DATA
MAXIMUM CAPACITY, MGD
1
10
100
1,000
CONSTRUCTION COST, $1,000
10
100
1,000

FIGURE 2

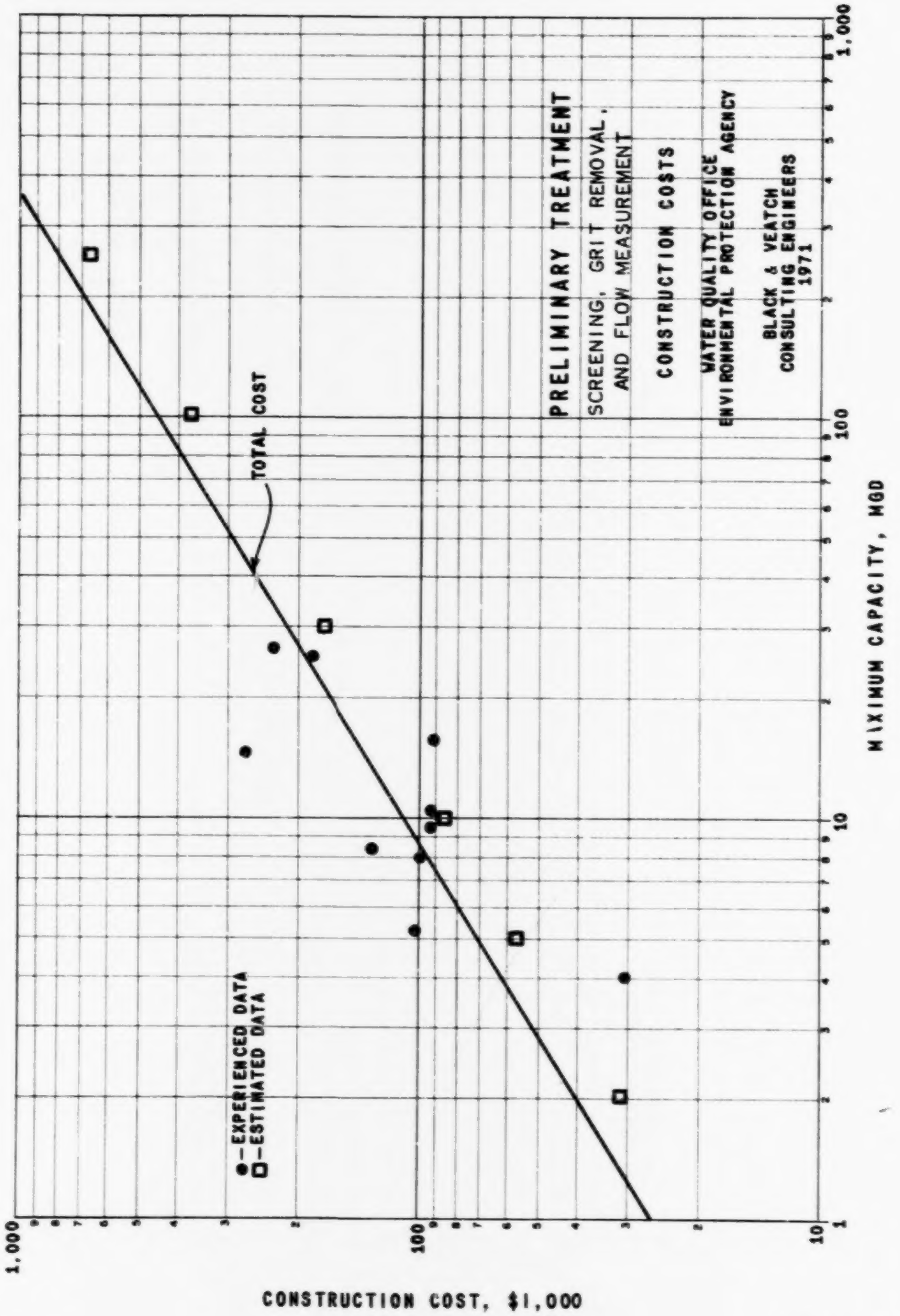

PRELIMINARY TREATMENT
SCREENING, GRIT REMOVAL, AND FLOW MEASUREMENT
CONSTRUCTION COSTS
WATER QUALITY OFFICE
ENVIRONMENTAL PROTECTION AGENCY
BLACK & VEATCH
CONSULTING ENGINEERS
1971
● - EXPERIENCED DATA
□ - ESTIMATED DATA
TOTAL COST
MAXIMUM CAPACITY, MGD
1
10
100
1,000
CONSTRUCTION COST, $1,000
10
100
1,000

FIGURE 3

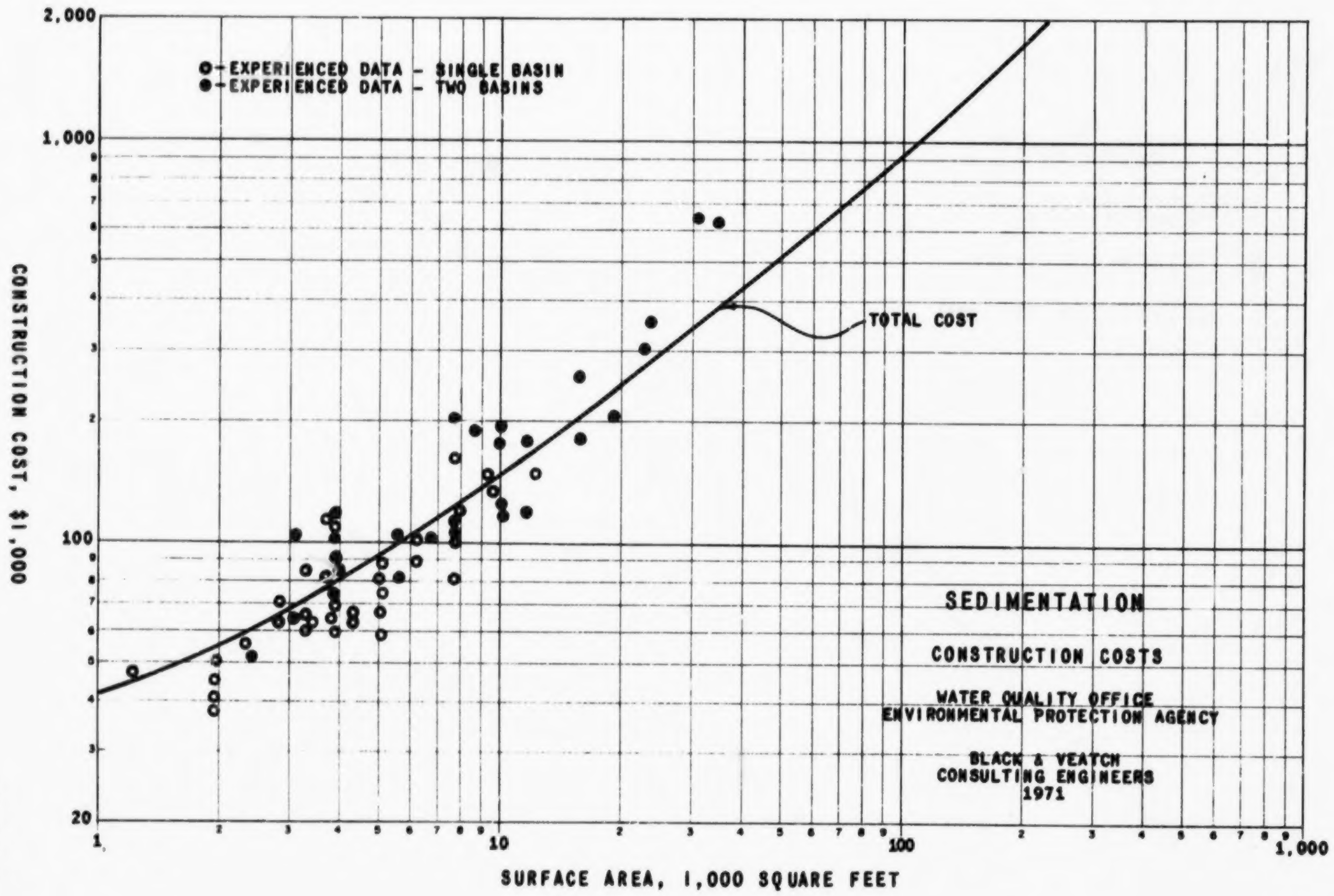
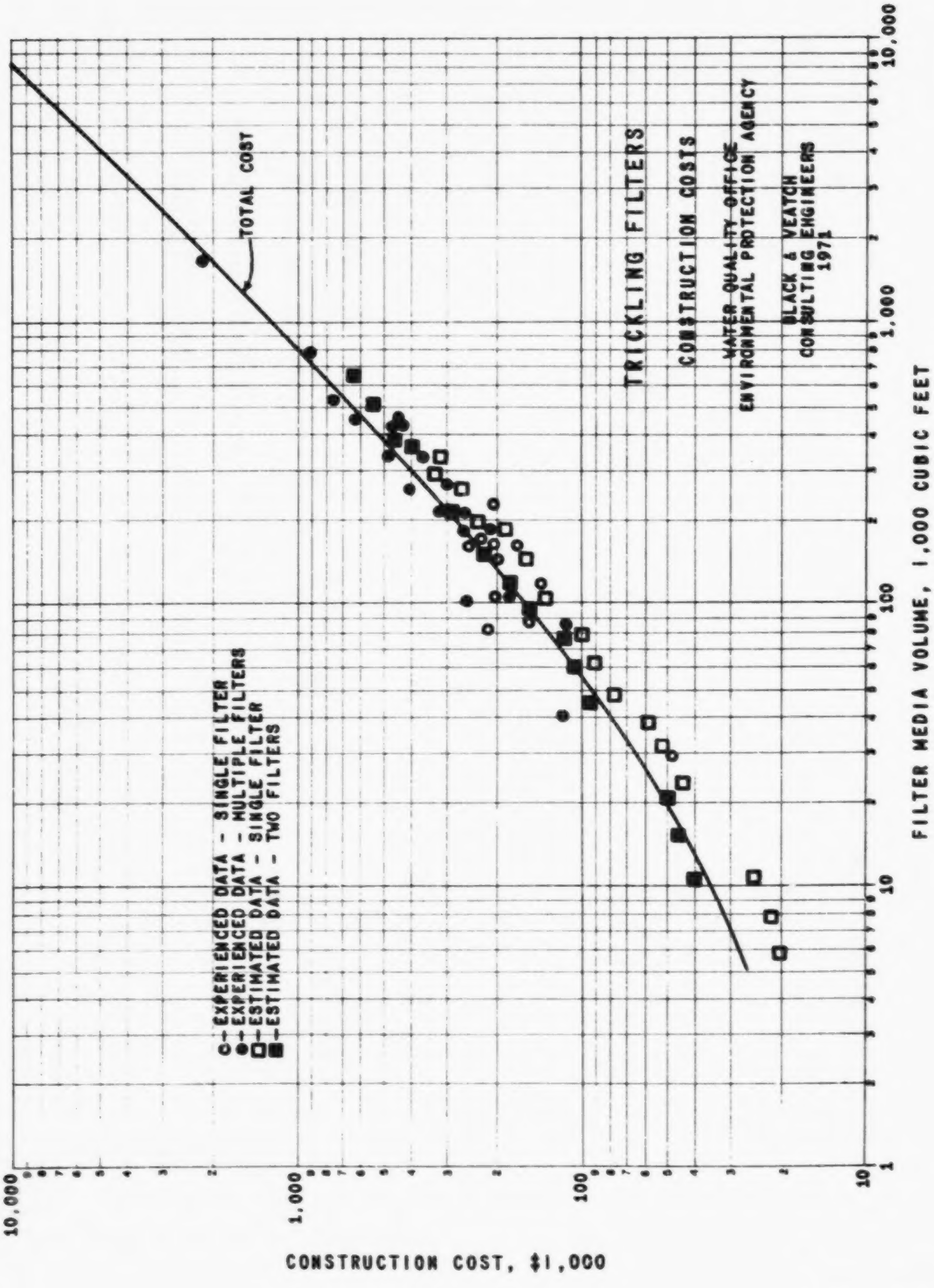

○ - EXPERIENCED DATA - SINGLE BASIN
● - EXPERIENCED DATA - TWO BASINS
TOTAL COST
SEDIMENTATION
CONSTRUCTION COSTS
WATER QUALITY OFFICE
ENVIRONMENTAL PROTECTION AGENCY
BLACK & VEATCH
CONSULTING ENGINEERS
1971
CONSTRUCTION COST, $1,000
2,000
1,000
100
20
SURFACE AREA, 1,000 SQUARE FEET
1
10
100
1,000

FIGURE 4



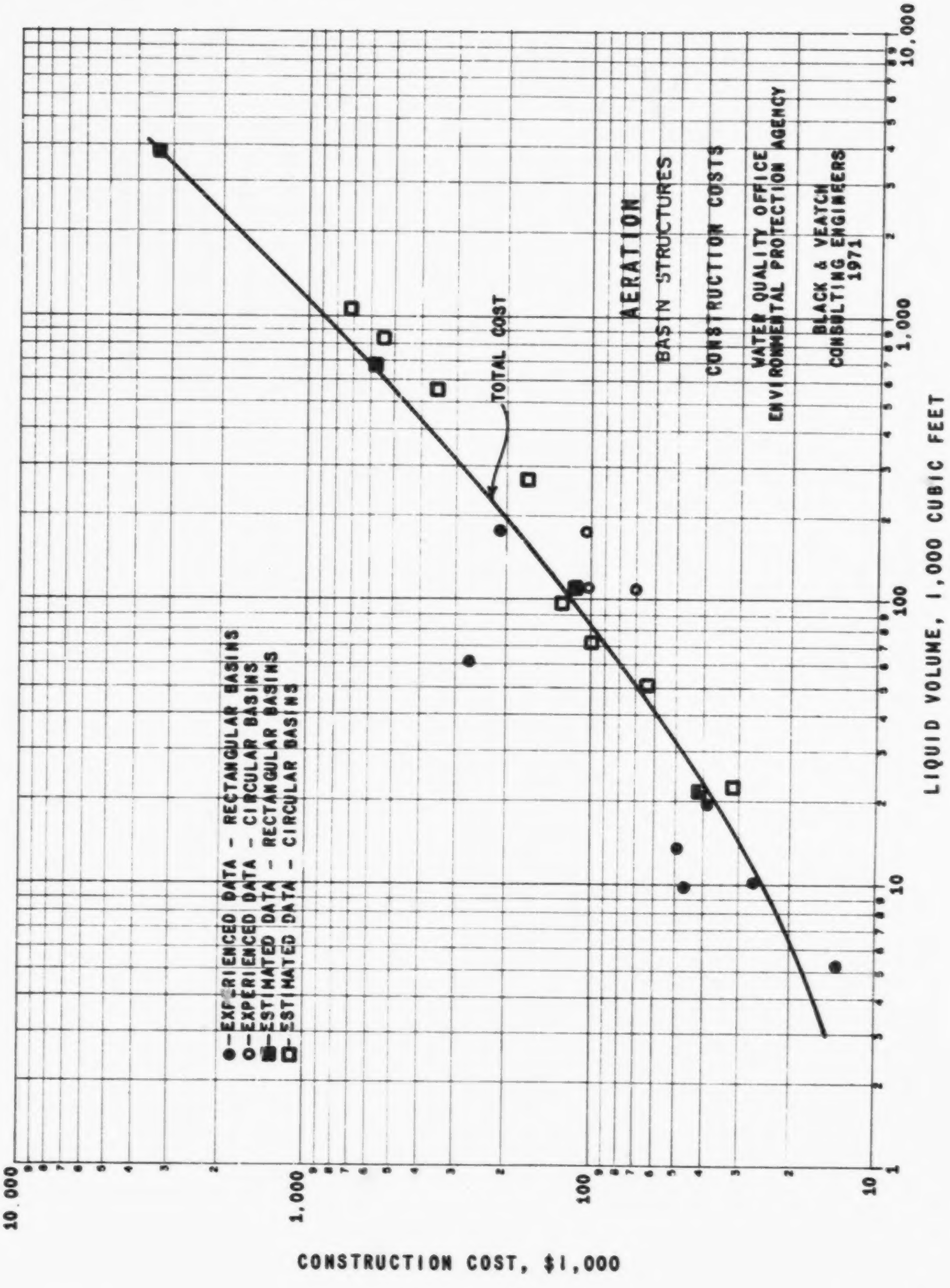
TRICKLING FILTERS

CONSTRUCTION COSTS

WATER QUALITY OFFICE
ENVIRONMENTAL PROTECTION AGENCY

BLACK & VEATCH
CONSULTING ENGINEERS
1971

FIGURE 5



●— EXPERIENCED DATA - RECTANGULAR BASINS
○— EXPERIENCED DATA - CIRCULAR BASINS
■— ESTIMATED DATA - RECTANGULAR BASINS
□— ESTIMATED DATA - CIRCULAR BASINS
TOTAL COST
AERATION
BASIN STRUCTURES
CONSTRUCTION COSTS
WATER QUALITY OFFICE
ENVIRONMENTAL PROTECTION AGENCY
BLACK & VEATCH
CONSULTING ENGINEERS
1971
LIQUID VOLUME, 1,000 CUBIC FEET
1
10
100
1,000
10,000
CONSTRUCTION COST, $1,000
10
100
1,000
10,000

FIGURE 6

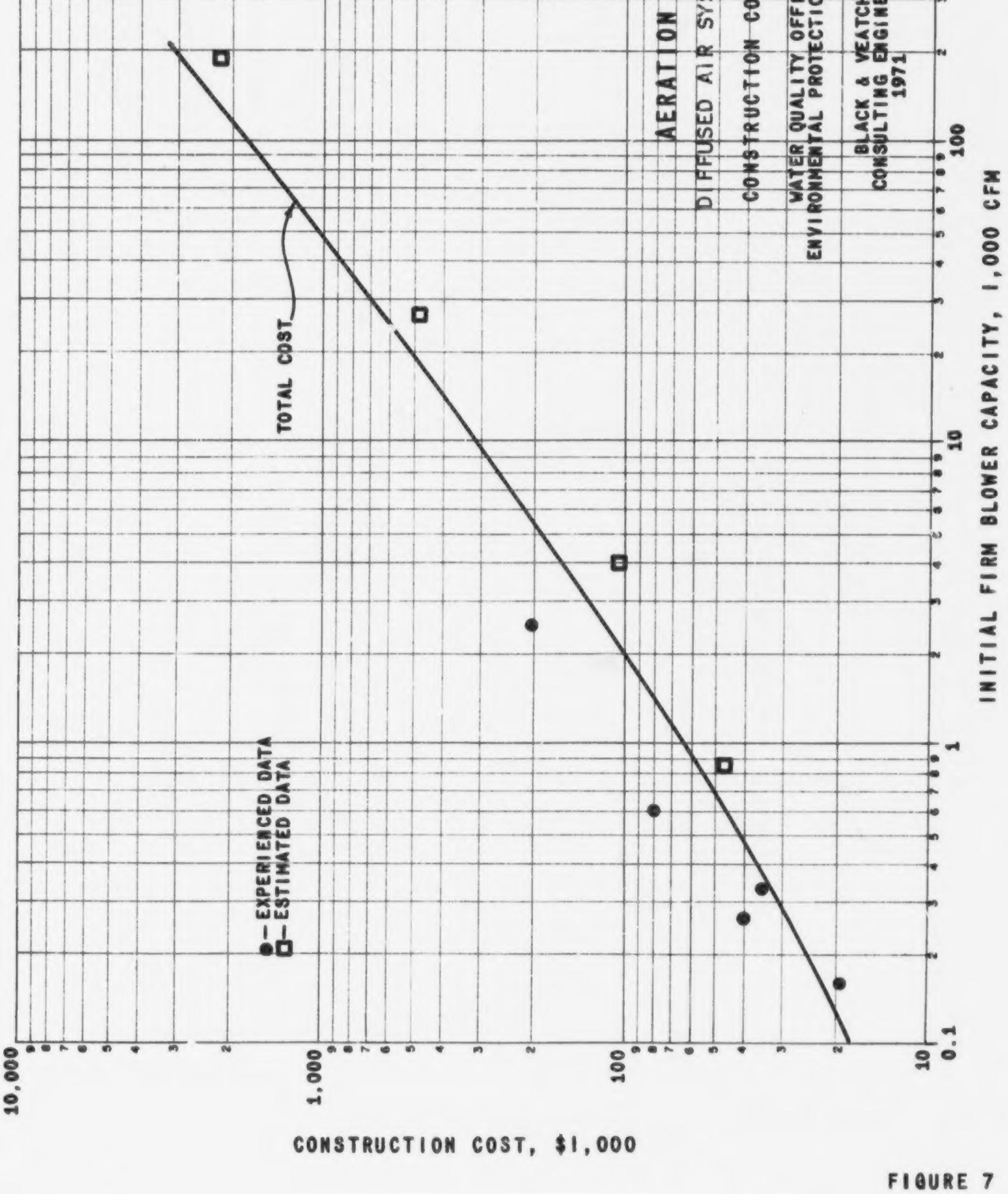

AERATION
DIFFUSED AIR SYSTEM
CONSTRUCTION COSTS
WATER QUALITY OFFICE
ENVIRONMENTAL PROTECTION AGENCY
BLACK & VEATCH
CONSULTING ENGINEERS
1971
TOTAL COST
● — EXPERIENCED DATA
□ — ESTIMATED DATA
INITIAL FIRM BLOWER CAPACITY, 1,000 CFM
0.1
1
10
100
CONSTRUCTION COST, $1,000
10
100
1,000
10,000

FIGURE 7

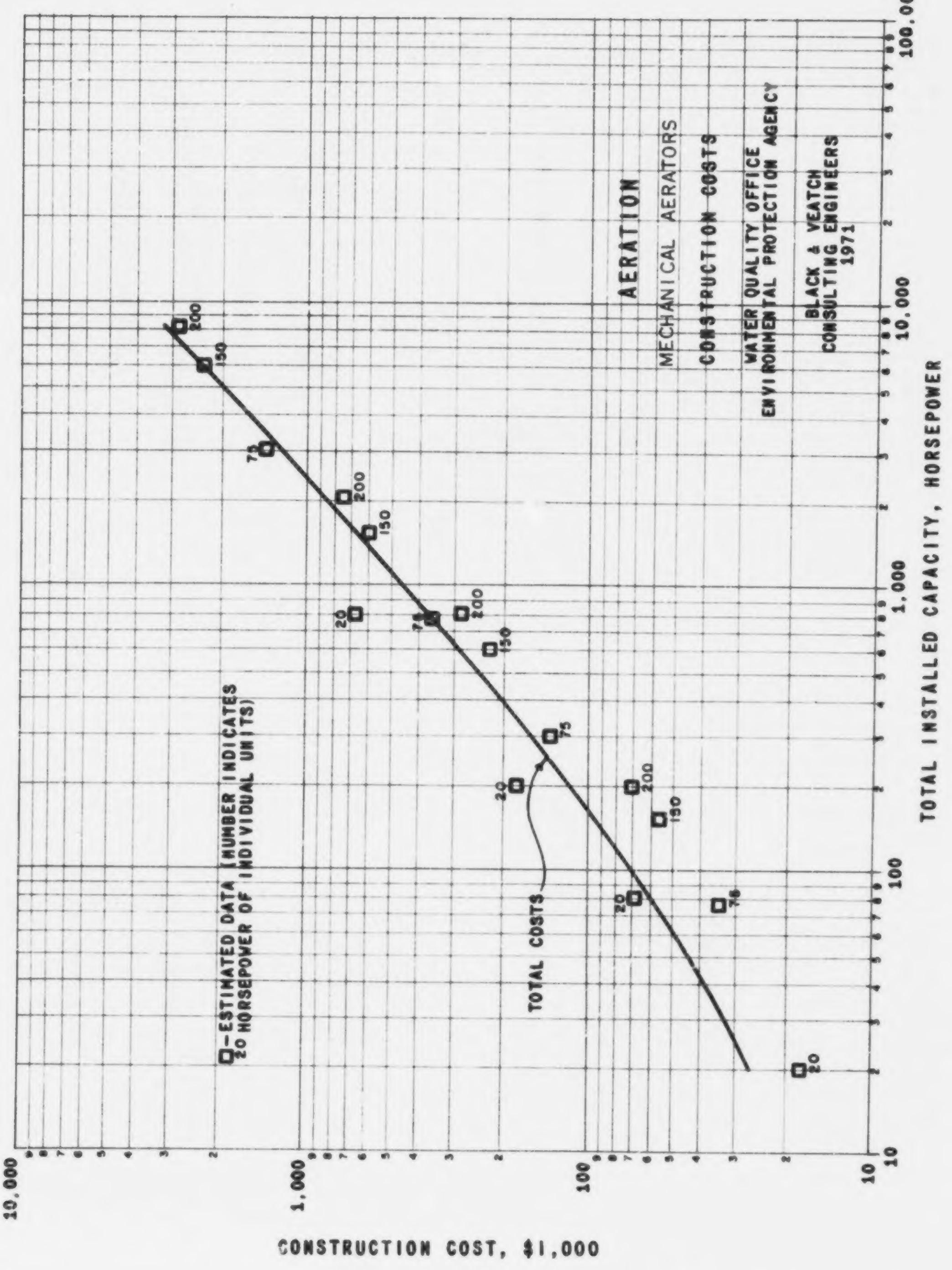

AERATION
MECHANICAL AERATORS
CONSTRUCTION COSTS
WATER QUALITY OFFICE
ENVIRONMENTAL PROTECTION AGENCY
BLACK & VEATCH
CONSULTING ENGINEERS
1971
□ - ESTIMATED DATA (NUMBER INDICATES
20 HORSEPOWER OF INDIVIDUAL UNITS)
TOTAL COSTS
TOTAL INSTALLED CAPACITY, HORSEPOWER
CONSTRUCTION COST, $1,000
10
100
1,000
10,000
100,000
10
100
1,000
10,000
200
150
75
200
150
20
75
200
150
75
20
200
150
20
75
20

FIGURE 8

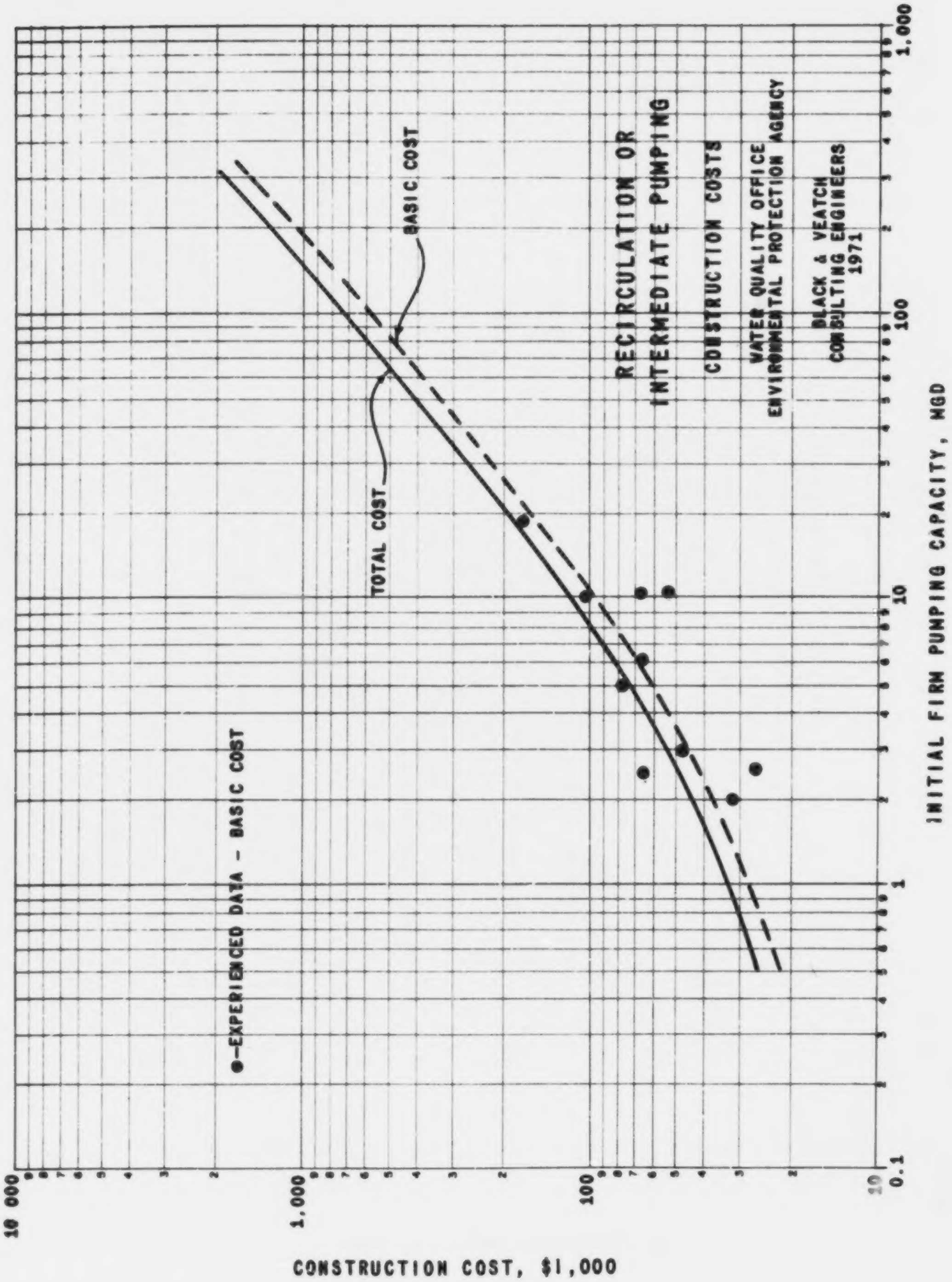

RECIRCULATION OR INTERMEDIATE PUMPING
CONSTRUCTION COSTS
WATER QUALITY OFFICE
ENVIRONMENTAL PROTECTION AGENCY
BLACK & VEATCH
CONSULTING ENGINEERS
1971
BASIC COST
TOTAL COST
●—EXPERIENCED DATA - BASIC COST
INITIAL FIRM PUMPING CAPACITY, MGD
0.1
1
10
100
1,000
CONSTRUCTION COST, $1,000
10
100
1,000
10 000

FIGURE 9

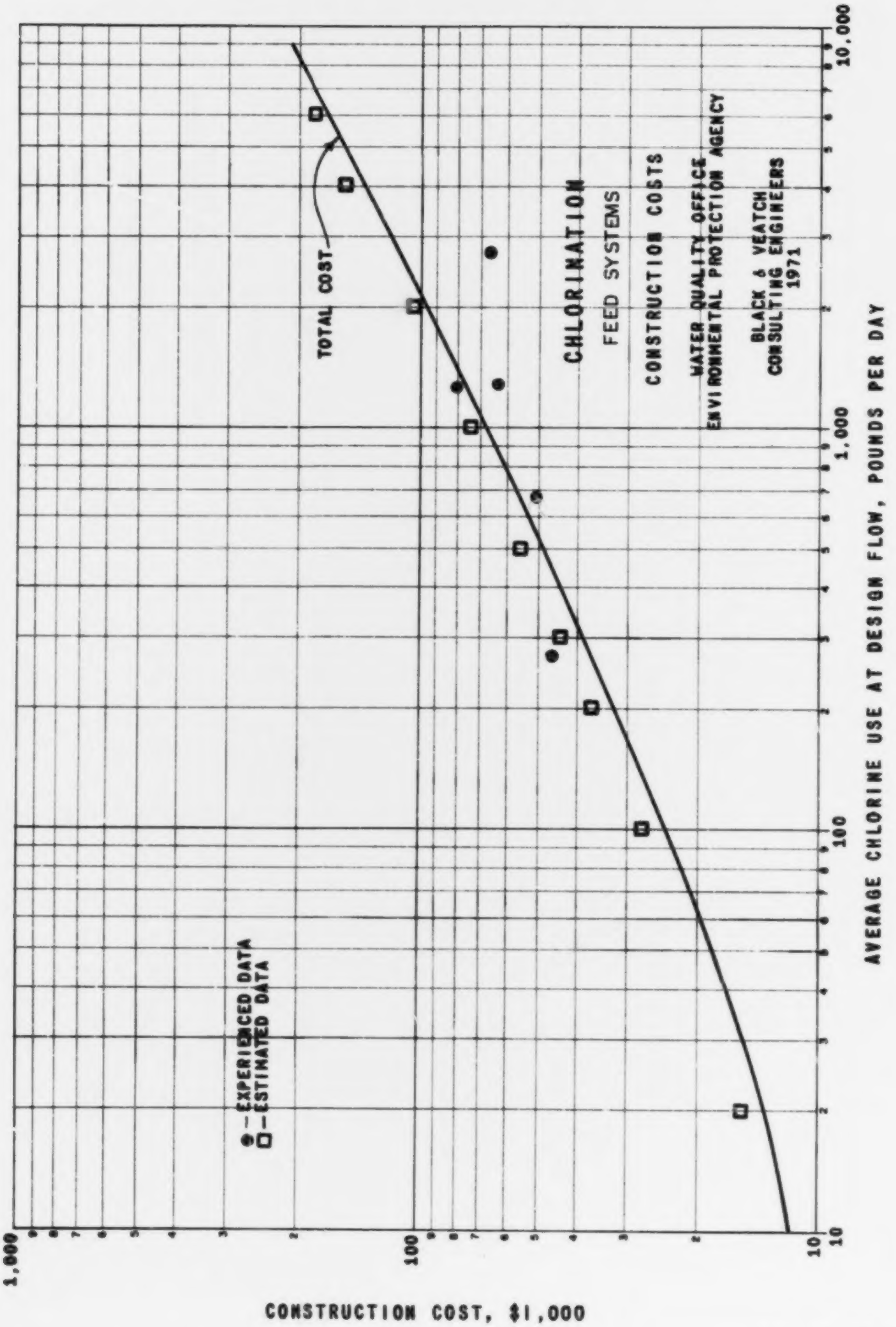

CHLORINATION
FEED SYSTEMS
CONSTRUCTION COSTS
WATER QUALITY OFFICE
ENVIRONMENTAL PROTECTION AGENCY
BLACK & VEATCH
CONSULTING ENGINEERS
1971
TOTAL COST
● — EXPERIENCED DATA
□ — ESTIMATED DATA
AVERAGE CHLORINE USE AT DESIGN FLOW, POUNDS PER DAY
10
100
1,000
10,000
CONSTRUCTION COST, $1,000
10
100
1,000

FIGURE 10

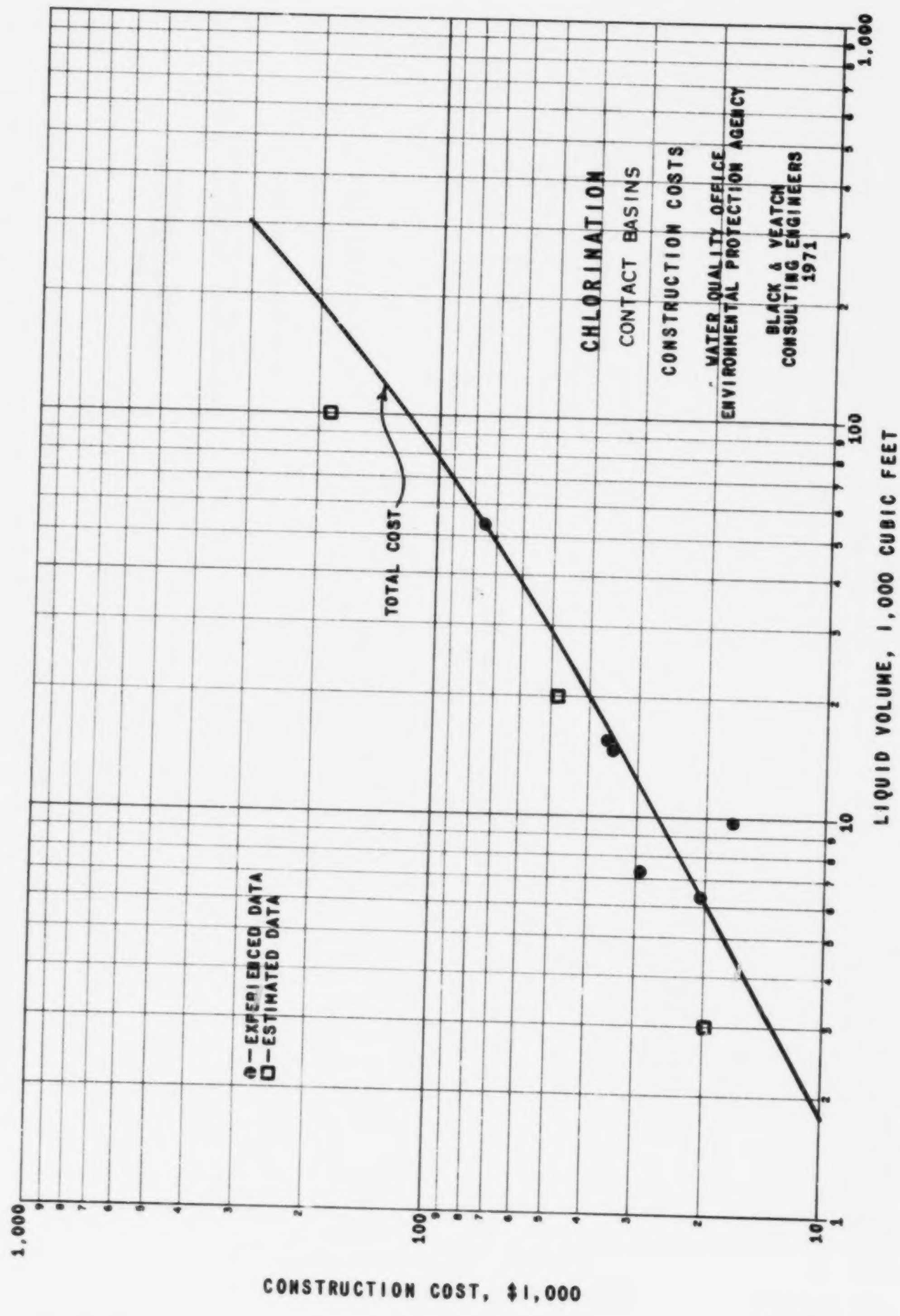

CHLORINATION
CONTACT BASINS
CONSTRUCTION COSTS
WATER QUALITY OFFICE
ENVIRONMENTAL PROTECTION AGENCY
BLACK & VEATCH
CONSULTING ENGINEERS
1971
TOTAL COST
●—EXPERIENCED DATA
□—ESTIMATED DATA
1
10
100
1,000
LIQUID VOLUME, 1,000 CUBIC FEET
10
100
1,000
CONSTRUCTION COST, $1,000

FIGURE 11

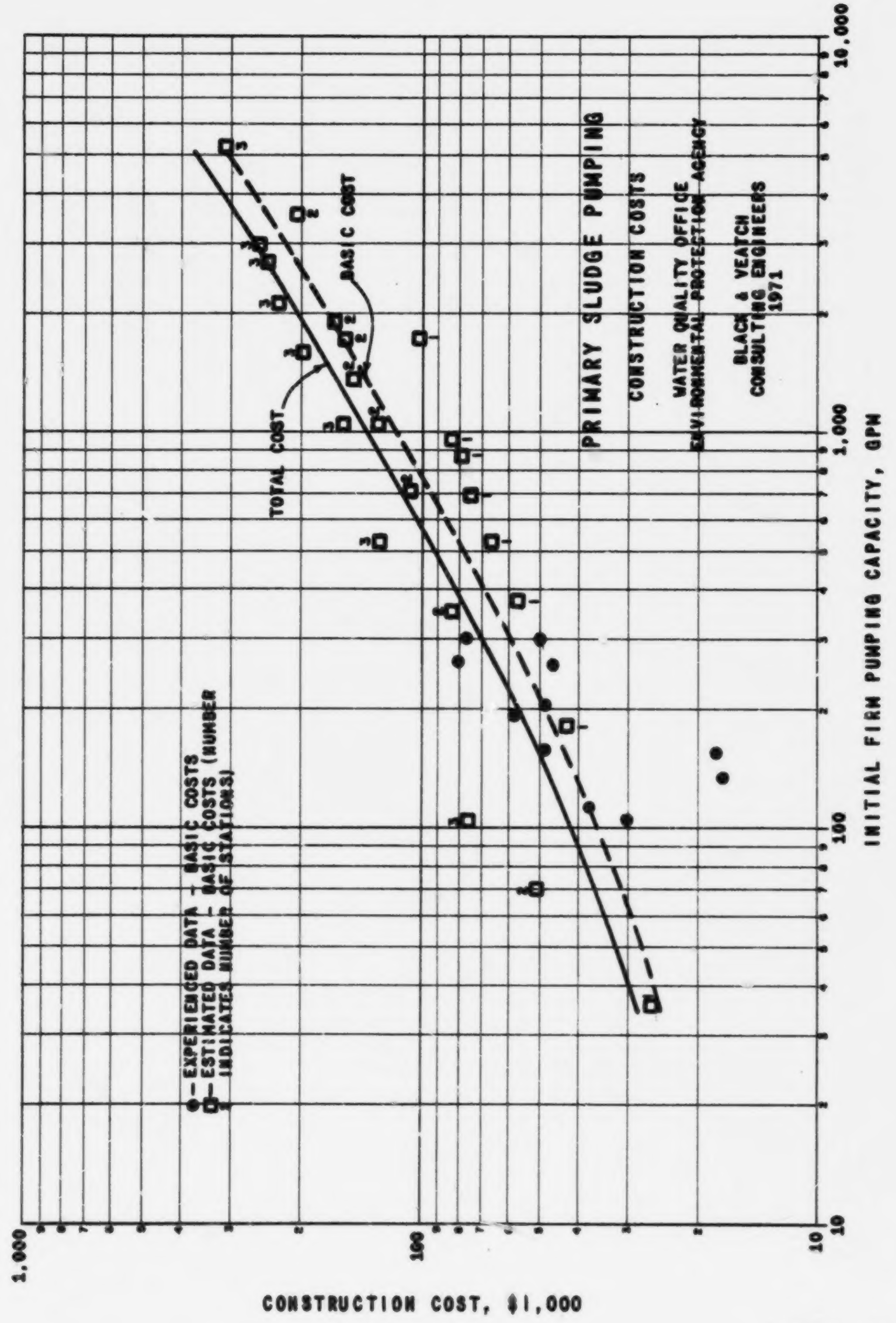
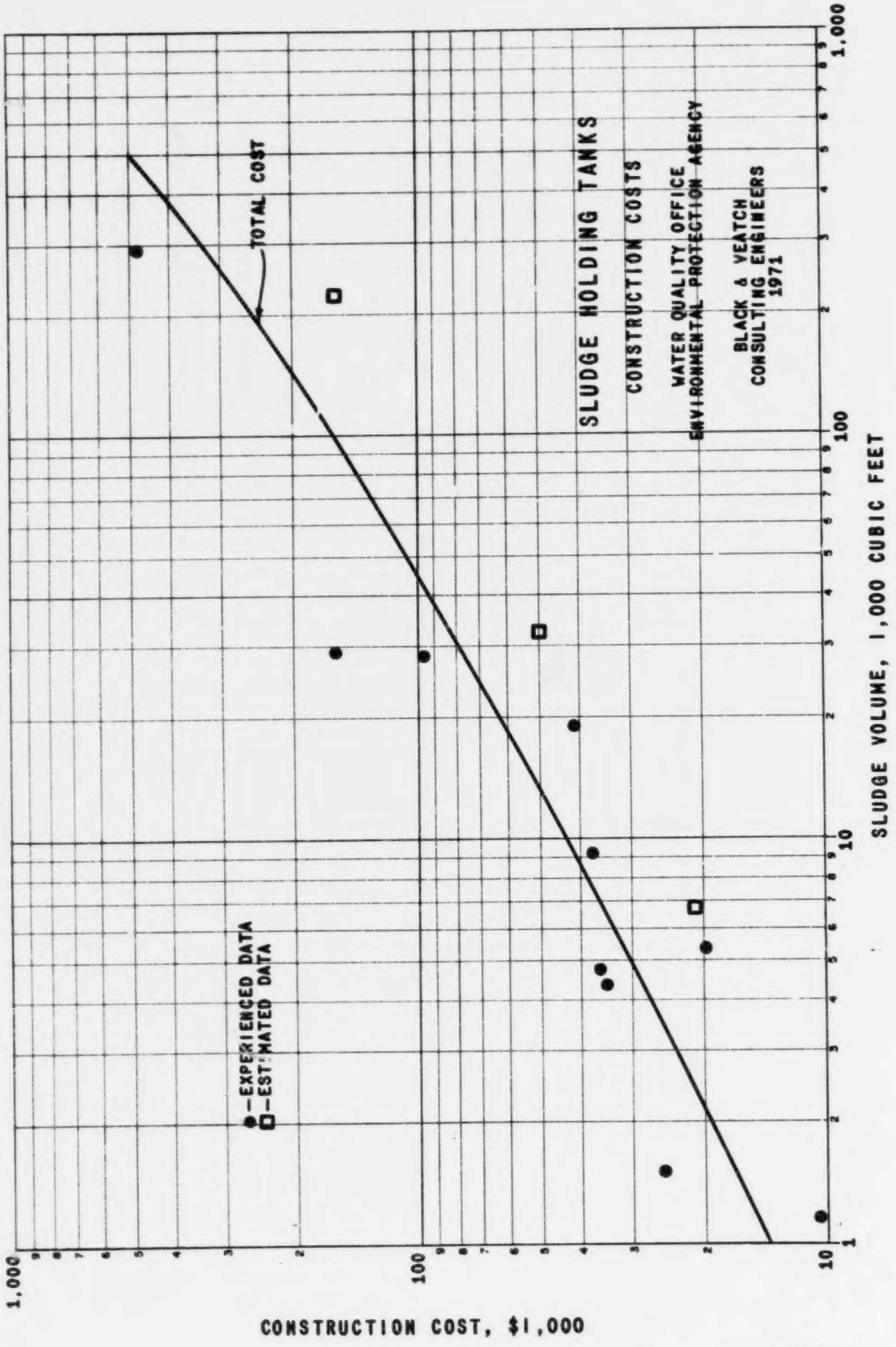

PRIMARY SLUDGE PUMPING
CONSTRUCTION COSTS
WATER QUALITY OFFICE
ENVIRONMENTAL PROTECTION AGENCY
BLACK & VEATCH
CONSULTING ENGINEERS
1971
● – EXPERIENCED DATA – BASIC COSTS
□ – ESTIMATED DATA – BASIC COSTS (NUMBER INDICATES NUMBER OF STATIONS)
TOTAL COST
BASIC COST
10
100
1,000
10,000
INITIAL FIRM PUMPING CAPACITY, GPM
10
100
1,000
CONSTRUCTION COST, $1,000

FIGURE 12


SLUDGE HOLDING TANKS

CONSTRUCTION COSTS

WATER QUALITY OFFICE
ENVIRONMENTAL PROTECTION AGENCY

BLACK & VEATCH
CONSULTING ENGINEERS
1971

FIGURE 13

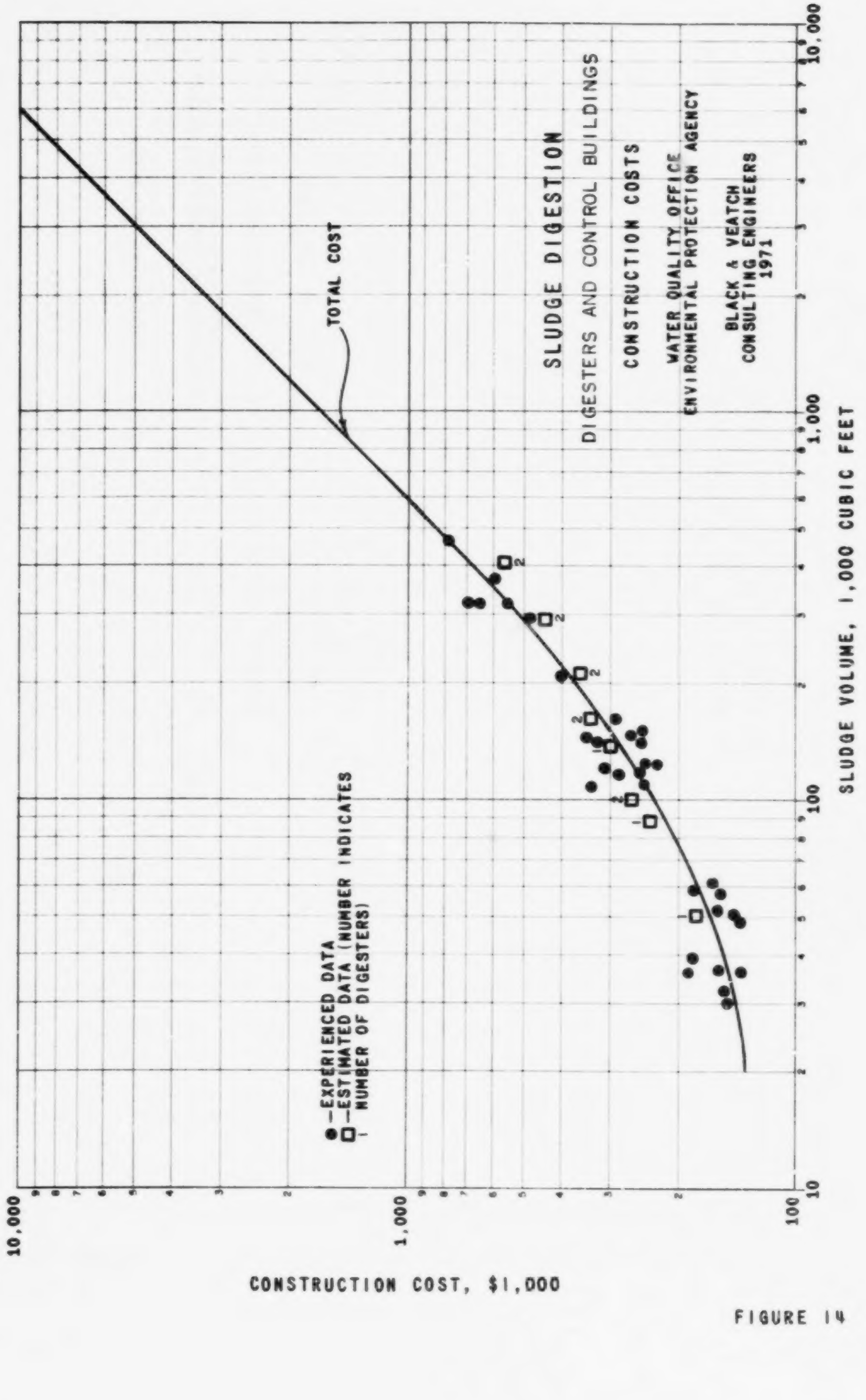

SLUDGE DIGESTION
DIGESTERS AND CONTROL BUILDINGS
CONSTRUCTION COSTS
WATER QUALITY OFFICE
ENVIRONMENTAL PROTECTION AGENCY
BLACK & VEATCH
CONSULTING ENGINEERS
1971
TOTAL COST
● —EXPERIENCED DATA
□ —ESTIMATED DATA (NUMBER INDICATES
1 NUMBER OF DIGESTERS)
SLUDGE VOLUME, 1,000 CUBIC FEET
CONSTRUCTION COST, $1,000
10
100
1,000
10,000
100
1,000
10,000
2
1

FIGURE 14

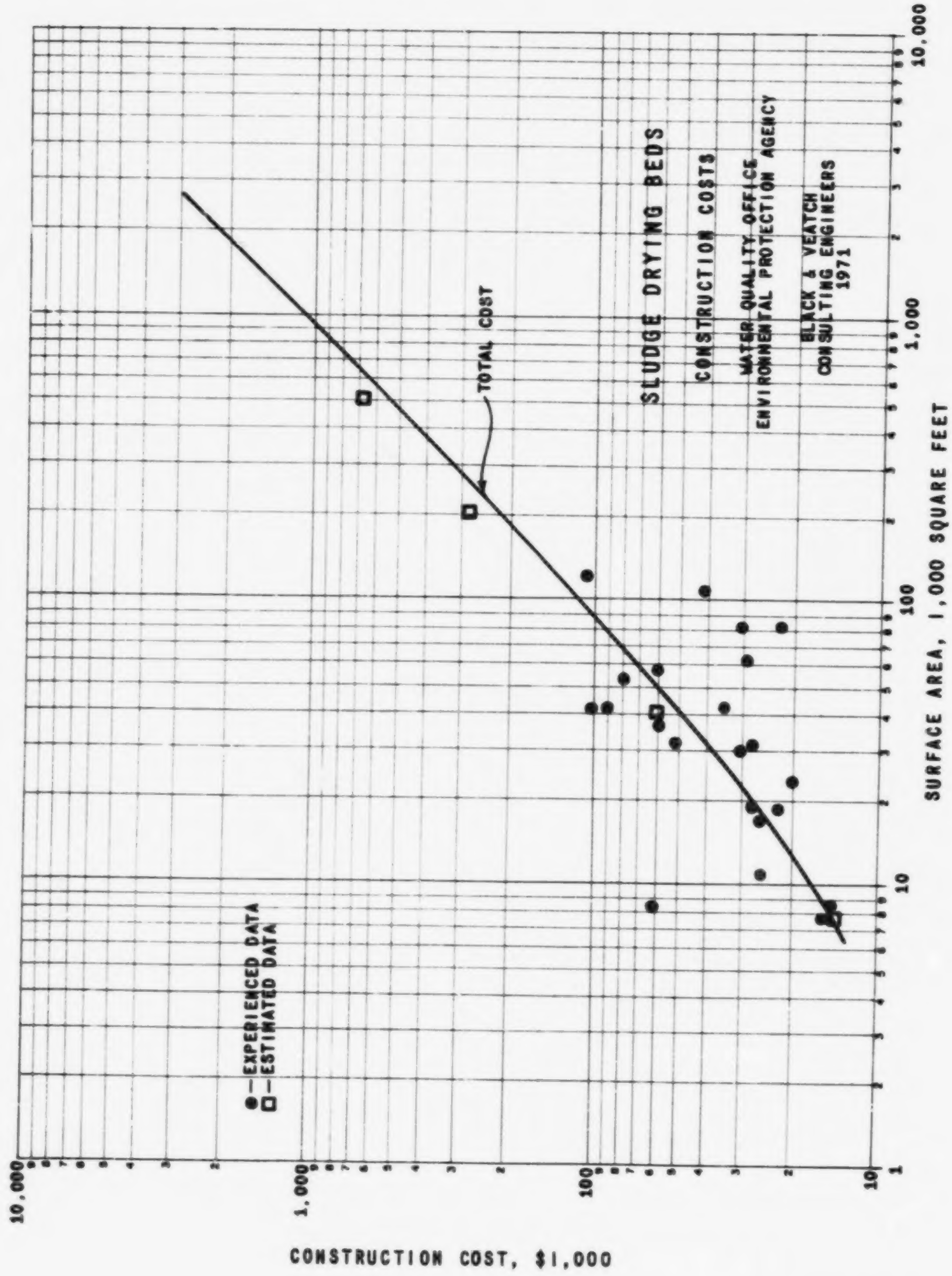

SLUDGE DRYING BEDS
CONSTRUCTION COSTS
WATER QUALITY OFFICE
ENVIRONMENTAL PROTECTION AGENCY
BLACK & VEATCH
CONSULTING ENGINEERS
1971
●—EXPERIENCED DATA
□—ESTIMATED DATA
TOTAL COST
SURFACE AREA, 1,000 SQUARE FEET
1
10
100
1,000
10,000
CONSTRUCTION COST, $1,000
10
100
1,000
10,000

FIGURE 15

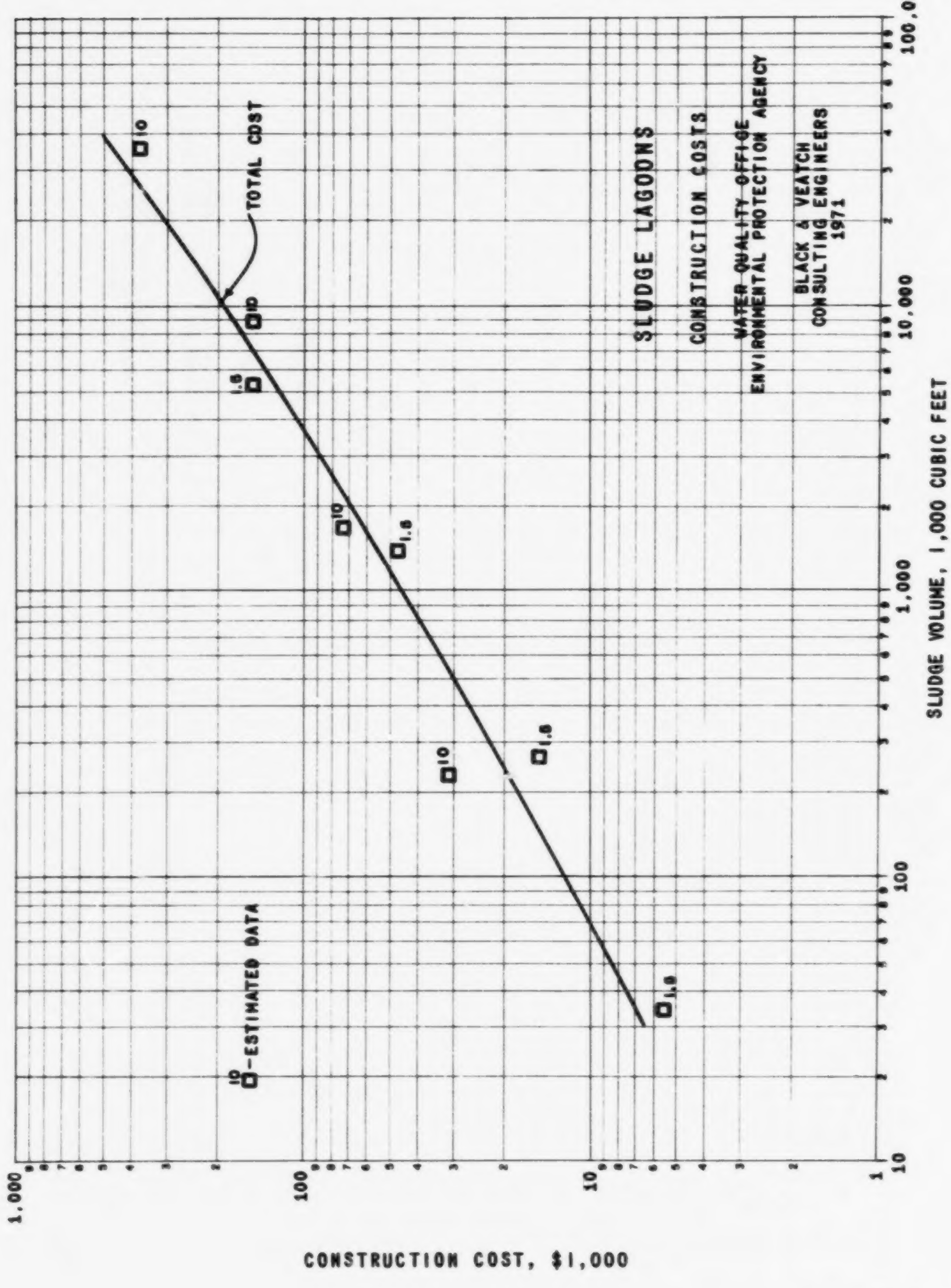

SLUDGE LAGOONS
CONSTRUCTION COSTS
WATER QUALITY OFFICE
ENVIRONMENTAL PROTECTION AGENCY
BLACK & VEATCH
CONSULTING ENGINEERS
1971
TOTAL COST
10 - ESTIMATED DATA
10
10
1.8
10
1.8
10
1.8
1.8
SLUDGE VOLUME, 1,000 CUBIC FEET
10
100
1,000
10,000
100,000
CONSTRUCTION COST, $1,000
1,000
100
10
1

FIGURE 16

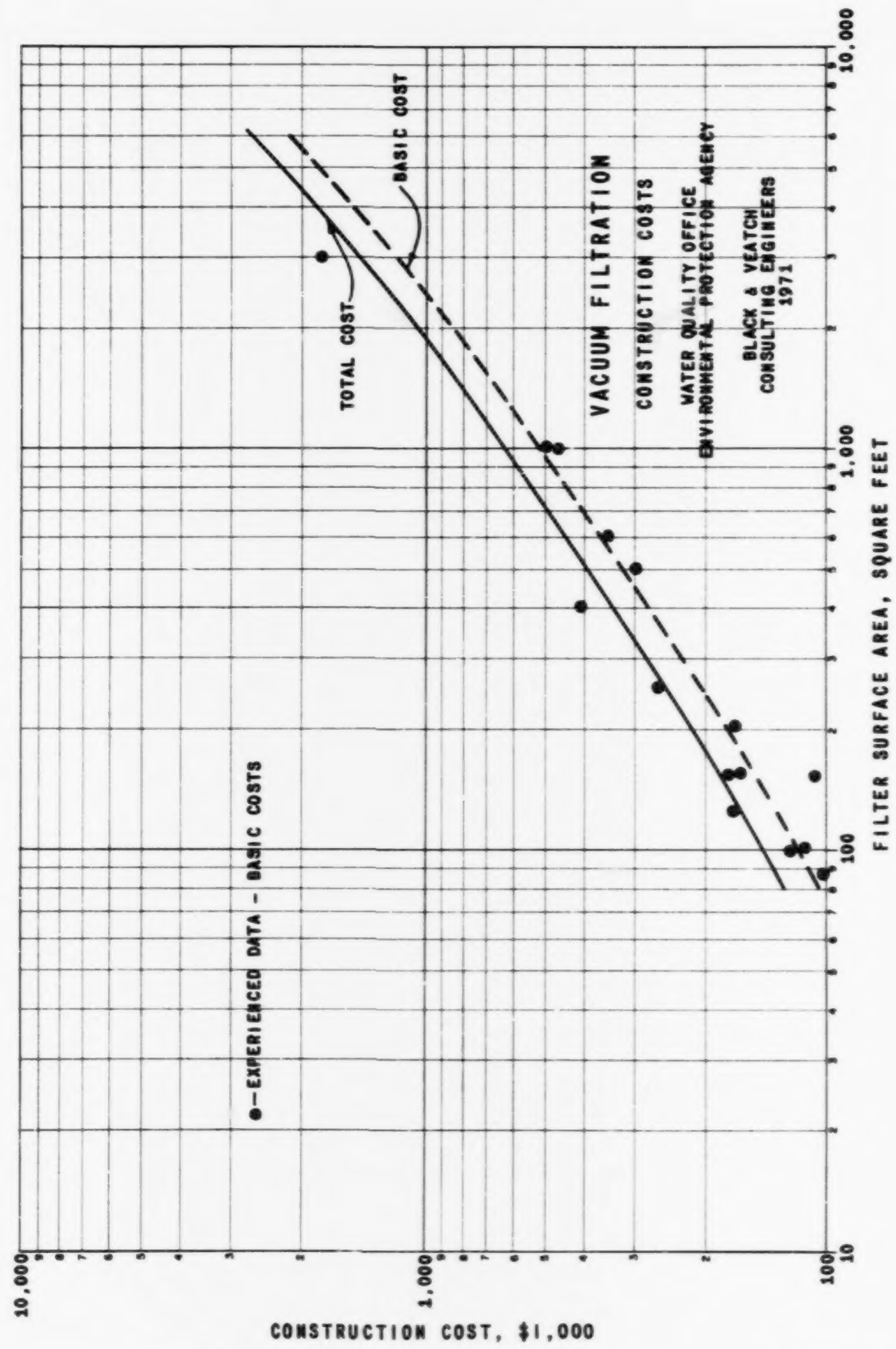

VACUUM FILTRATION
CONSTRUCTION COSTS
WATER QUALITY OFFICE
ENVIRONMENTAL PROTECTION AGENCY
BLACK & VEATCH
CONSULTING ENGINEERS
1971
TOTAL COST
BASIC COST
● — EXPERIENCED DATA - BASIC COSTS
FILTER SURFACE AREA, SQUARE FEET
10
100
1,000
10,000
CONSTRUCTION COST, $1,000
100
1,000
10,000

FIGURE 17

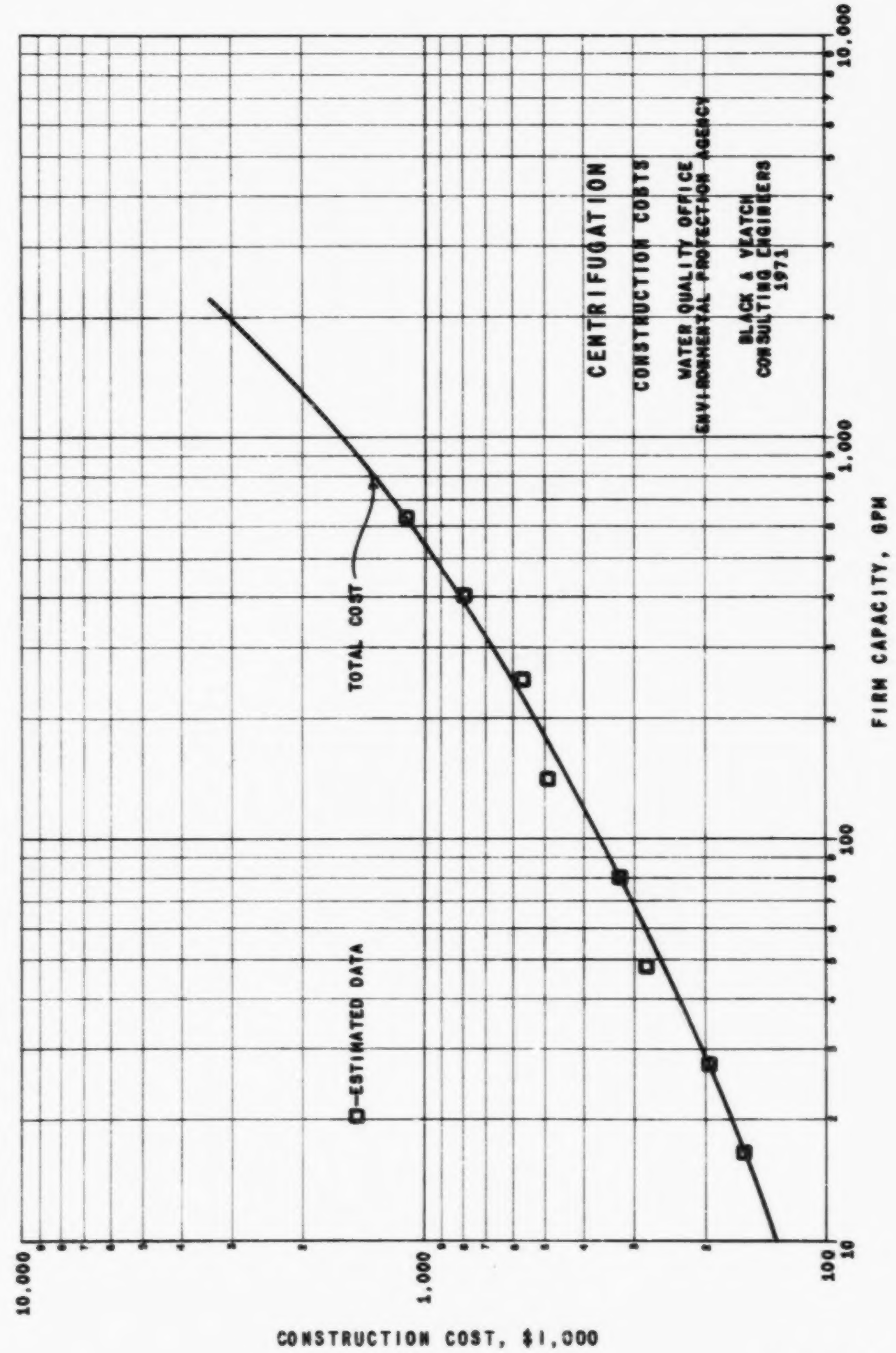

CENTRIFUGATION
CONSTRUCTION COSTS
WATER QUALITY OFFICE
ENVIRONMENTAL PROTECTION AGENCY
BLACK & VEATCH
CONSULTING ENGINEERS
1971
TOTAL COST
□—ESTIMATED DATA
FIRM CAPACITY, GPM
CONSTRUCTION COST, $1,000
10
100
1,000
10,000
100
1,000
10,000

FIGURE 18

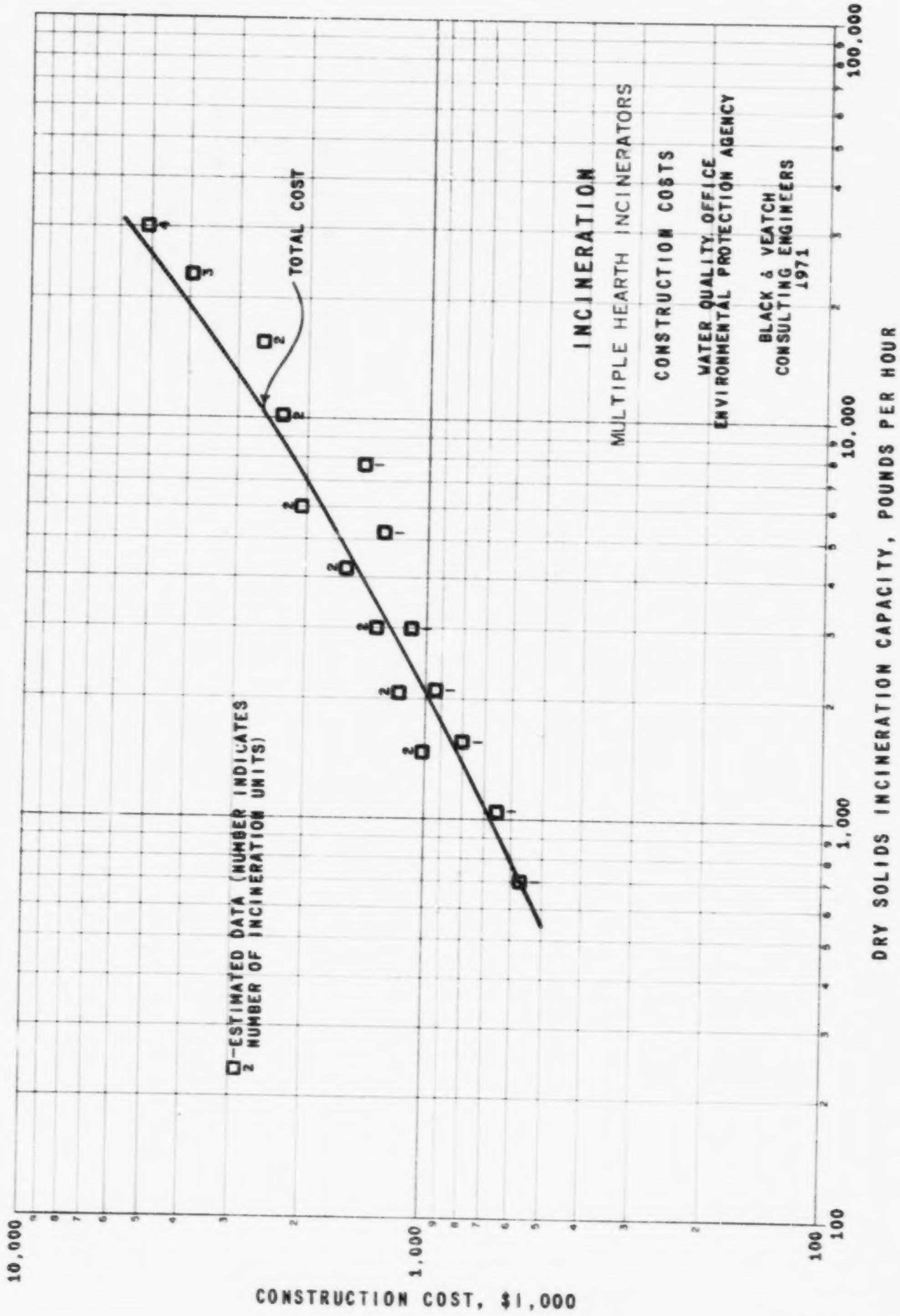

INCINERATION
MULTIPLE HEARTH INCINERATORS
CONSTRUCTION COSTS
WATER QUALITY OFFICE
ENVIRONMENTAL PROTECTION AGENCY
BLACK & VEATCH
CONSULTING ENGINEERS
1971
TOTAL COST
□ ESTIMATED DATA (NUMBER INDICATES NUMBER OF INCINERATION UNITS)
DRY SOLIDS INCINERATION CAPACITY, POUNDS PER HOUR
100
1,000
10,000
100,000
CONSTRUCTION COST, $1,000
100
1,000
10,000

FIGURE 19

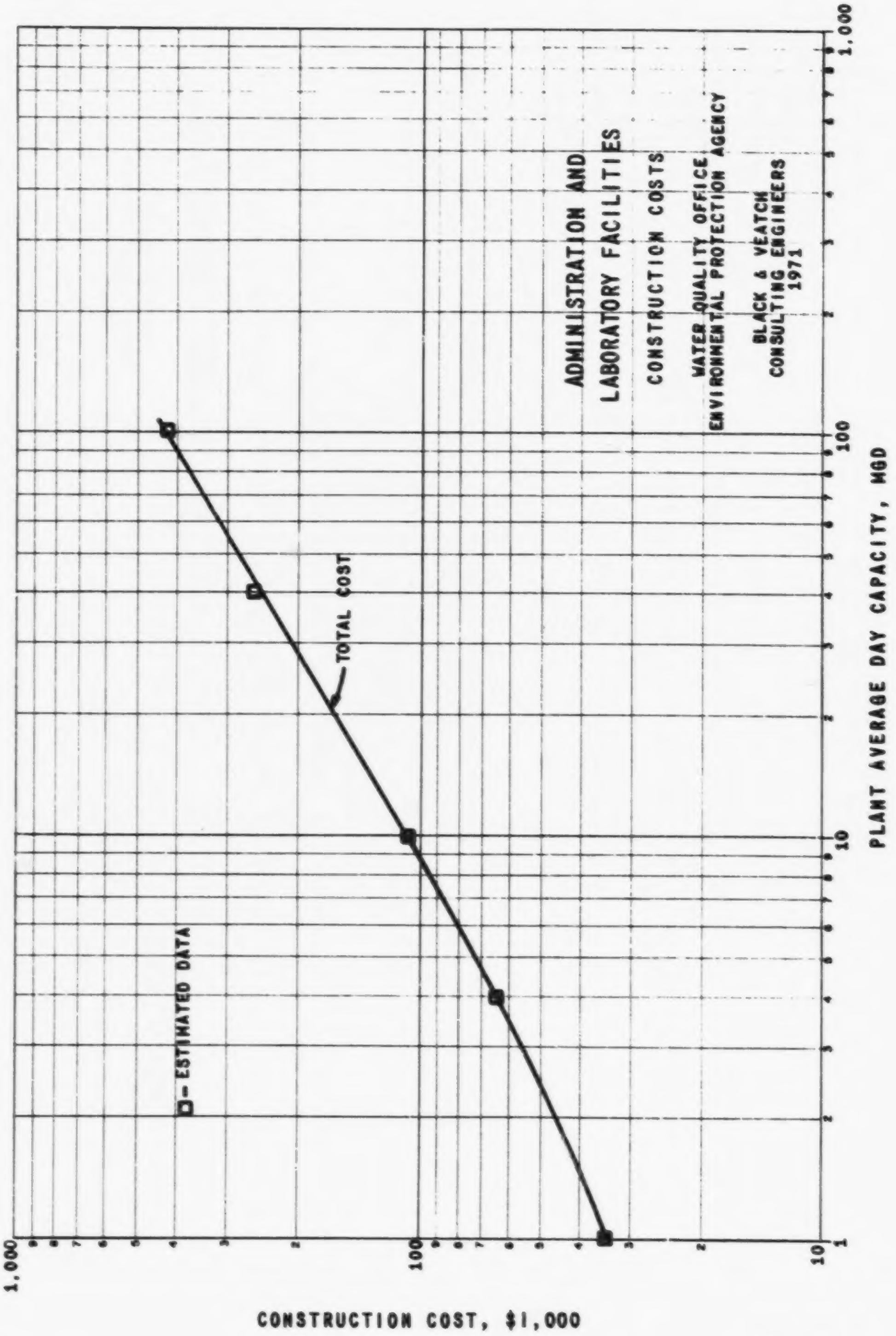
ADMINISTRATION AND
LABORATORY FACILITIES
CONSTRUCTION COSTS
WATER QUALITY OFFICE
ENVIRONMENTAL PROTECTION AGENCY
BLACK & VEATCH
CONSULTING ENGINEERS
1971
TOTAL COST
□ - ESTIMATED DATA
PLANT AVERAGE DAY CAPACITY, MGD
1
10
100
1,000
CONSTRUCTION COST, $1,000
10
100
1,000

FIGURE 20

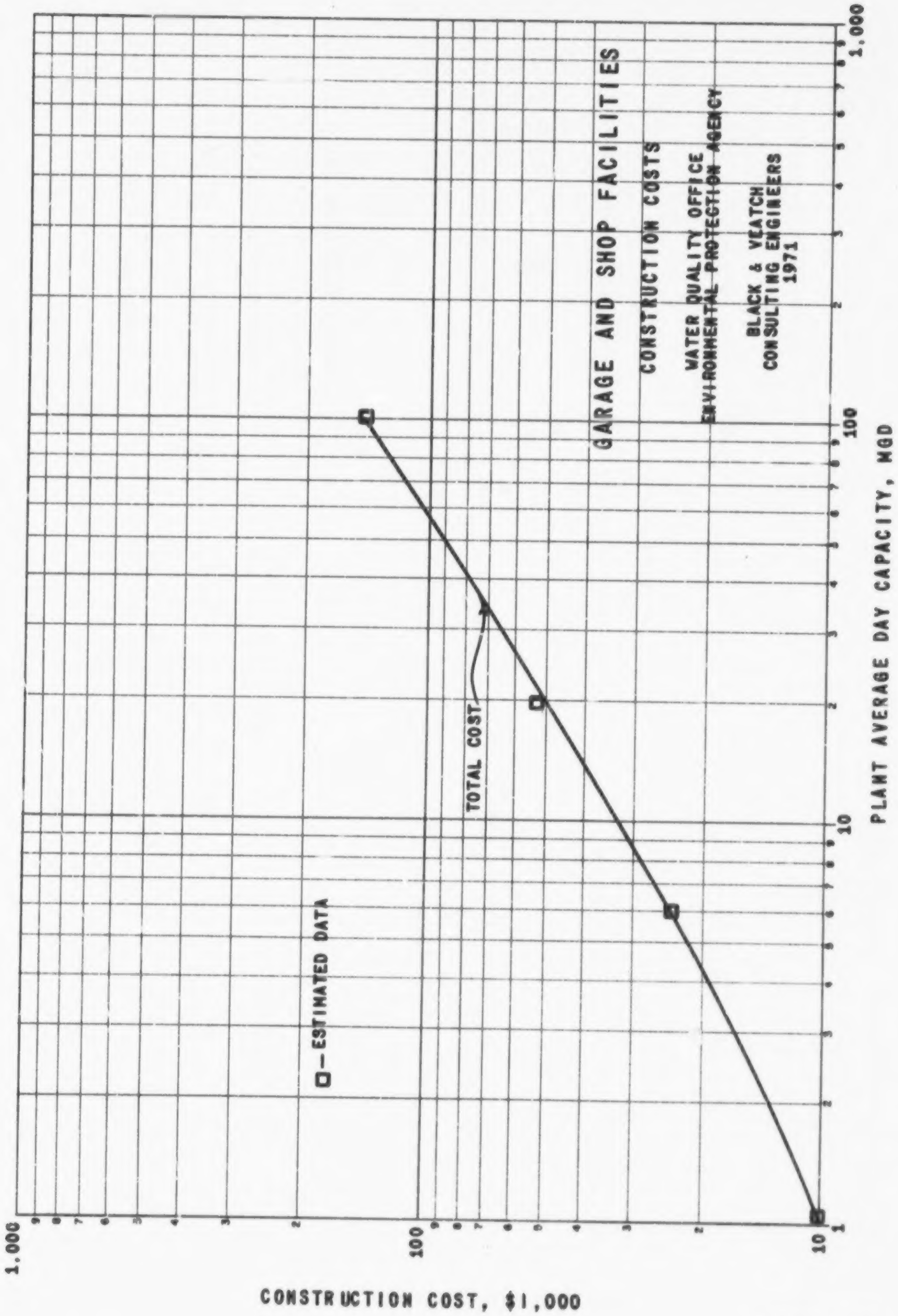
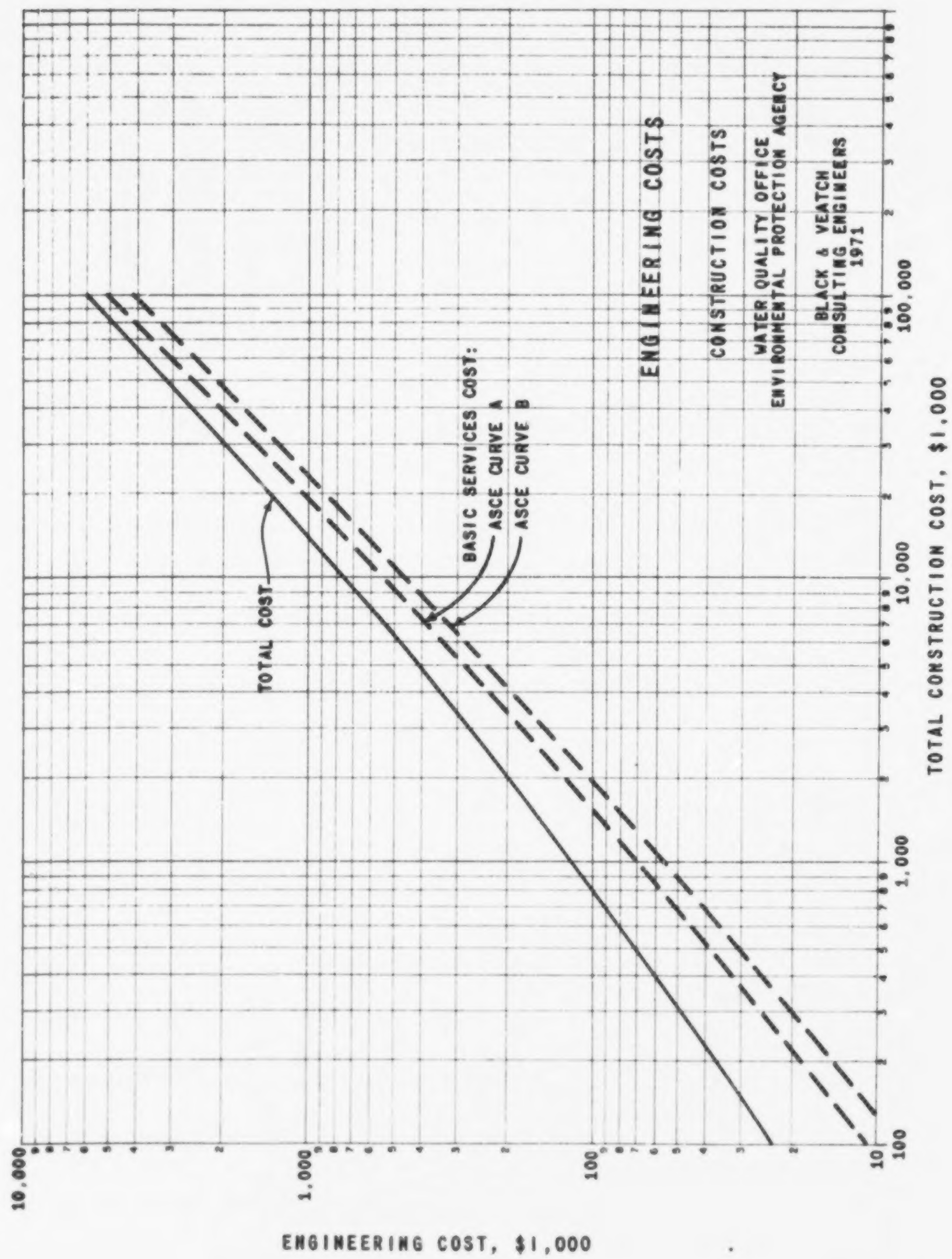

GARAGE AND SHOP FACILITIES
CONSTRUCTION COSTS
WATER QUALITY OFFICE
ENVIRONMENTAL PROTECTION AGENCY
BLACK & VEATCH
CONSULTING ENGINEERS
1971
TOTAL COST
□ — ESTIMATED DATA
PLANT AVERAGE DAY CAPACITY, MGD
1
10
100
1,000
CONSTRUCTION COST, $1,000
10
100
1,000

FIGURE 21



ENGINEERING COSTS

CONSTRUCTION COSTS

WATER QUALITY OFFICE
ENVIRONMENTAL PROTECTION AGENCY

BLACK & VEATCH
CONSULTING ENGINEERS
1971

FIGURE 22

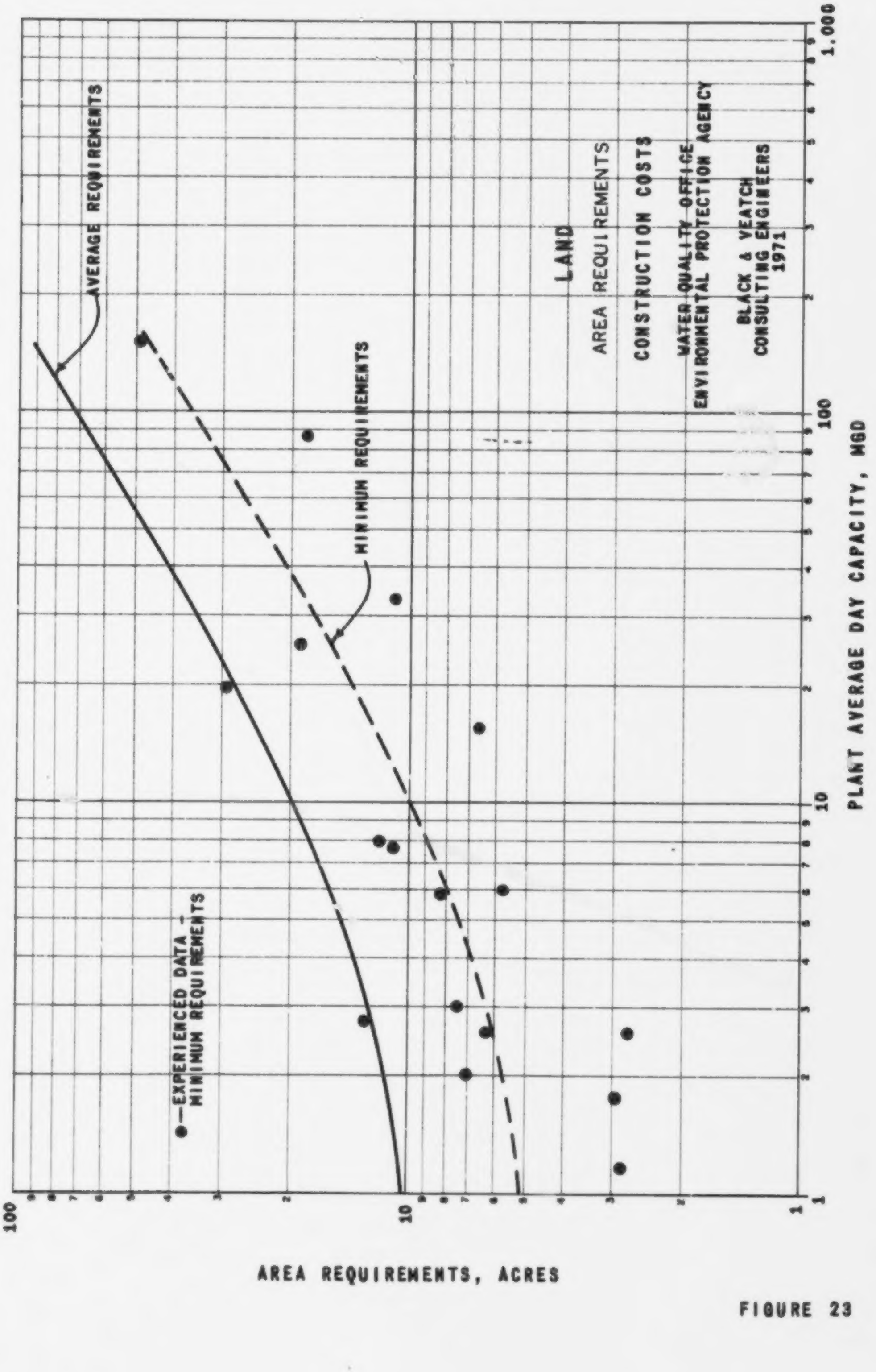

LAND
AREA REQUIREMENTS
CONSTRUCTION COSTS
WATER QUALITY OFFICE
ENVIRONMENTAL PROTECTION AGENCY
BLACK & VEATCH
CONSULTING ENGINEERS
1971
AVERAGE REQUIREMENTS
MINIMUM REQUIREMENTS
● —EXPERIENCED DATA - MINIMUM REQUIREMENTS
100
10
1
AREA REQUIREMENTS, ACRES
1
10
100
1,000
PLANT AVERAGE DAY CAPACITY, MGD

FIGURE 23

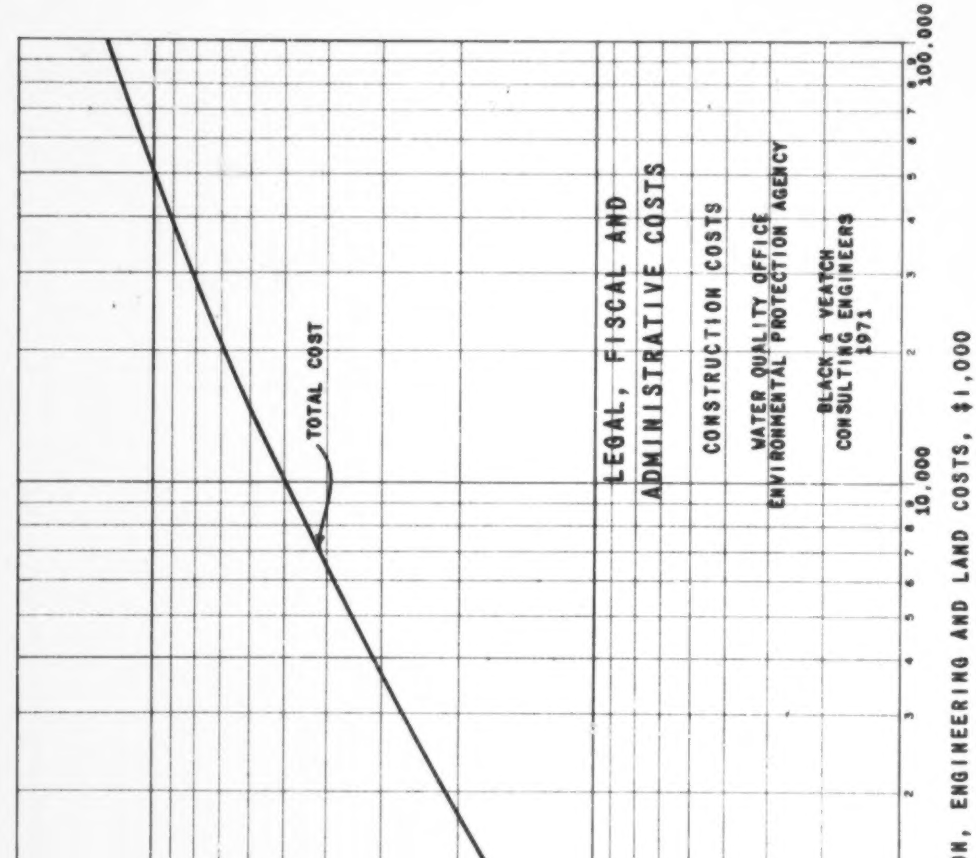
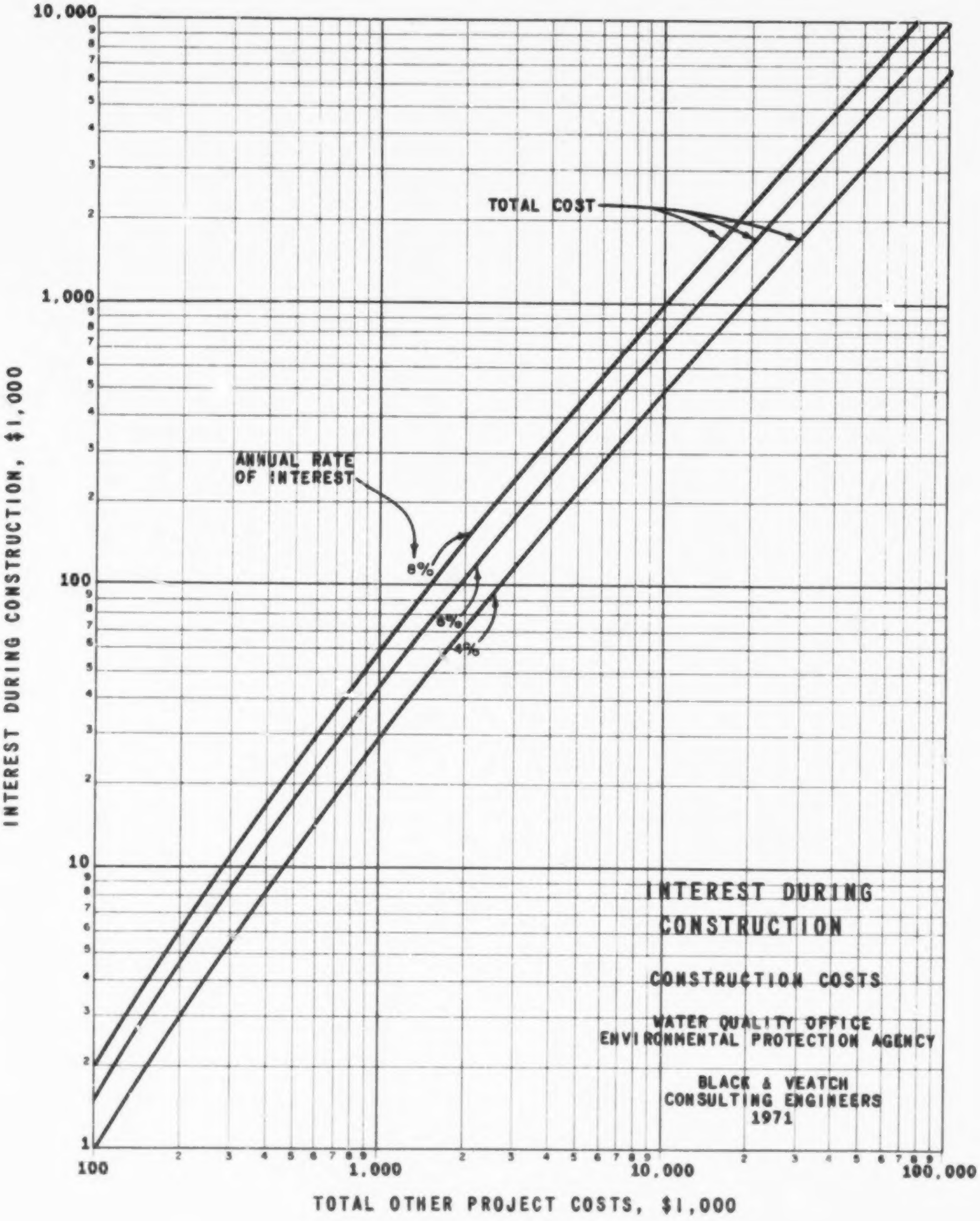

LEGAL, FISCAL AND ADMINISTRATIVE COSTS
CONSTRUCTION COSTS
WATER QUALITY OFFICE
ENVIRONMENTAL PROTECTION AGENCY
BLACK & VEATCH
CONSULTING ENGINEERS
1971
TOTAL COST
TOTAL CONSTRUCTION, ENGINEERING AND LAND COSTS, $1,000
100
1,000
10,000
100,000
200
100
10
2
LEGAL, FISCAL AND ADMINISTRATIVE COSTS, $1,000

FIGURE 24



INTEREST DURING CONSTRUCTION

CONSTRUCTION COSTS

WATER QUALITY OFFICE
ENVIRONMENTAL PROTECTION AGENCY

BLACK & VEATCH
CONSULTING ENGINEERS
1971

FIGURE 25

PART TWO - OPERATION AND MAINTENANCE COSTS

SECTION I

GENERAL CONSIDERATIONS

Part Two of this report develops means of estimating operation and maintenance costs of principal components of conventional wastewater treatment plants. Major elements of operation and maintenance cost considered include payroll man-hours for both operation and maintenance, and cost of materials and supplies. Each of the major cost elements is expressed in relation to appropriate sizing parameters for each of the principal plant components of conventional wastewater treatment plants.

Estimates of total operating expenses for various combinations of plant components may be developed on the basis of the average cost information presented. The cost estimating data are considered appropriate for facilities built in recent years which are in sound structural and operating condition. Estimates for new projects should recognize changing design and operating practice.

Operation and maintenance cost data for the various cost components have been developed by analyzing information obtained from existing operating facilities. Where field information was not available or insufficient, cost elements have been estimated. Cost estimating data generally reflect an average of current operations but have been adjusted where warranted to indicate sound operating conditions and procedures.

At the present time the average wastewater treatment facility is not highly automated and operation and maintenance estimating data presented reflect only the current type of operation. Automation will be more prevalent in plants built in the future, possibly reducing the manpower required to operate treatment facilities but, conversely, requiring more technical maintenance manpower.

Cost estimating data are based principally on information obtained from field investigation of actual operating wastewater systems. Plants considered for field investigation included a list of about 150 municipal facilities, compiled from current and previous experience of Black & Veatch, together with an extensive selection of plants developed through the cooperation of the regional offices of the Environmental Protection Agency and state water pollution control agencies. Criteria for their consideration included their being well operated with respect to the use of manpower, adequate cost records, efficiency of treatment, and condition of physical facilities. Over 100 of these cities, sanitary districts and sanitary authorities were contacted through correspondence for latest available operation and maintenance costs and plant staffing data. While many of the data obtained through correspondence were insufficient in detail for study purposes, they did indicate the general type of records available.

A total of 23 wastewater treatment plants were selected for field investigation, based upon consideration of the following characteristics:

1. Type of liquid and solids treatment facilities.
2. Adequacy of operation and maintenance cost records.
3. Design capacity.
4. Geographic location.

Plants investigated and their principal characteristics are identified in Table 2.

Standard information forms were prepared for the collection of on-site field investigation data at the plants visited. Data obtained regarding physical facilities at each of the 23 plants investigated included the size or capacity of component structures and major items of equipment, character of plant component operation and maintenance, and special comments about the facilities.

Manpower data obtained for each plant included the number of employees, by job classification,used to operate and maintain the plant; the allocation of each employee's time to plant components; the amount of unproductive time the plant employees are paid for, including vacations, sick leave, and holidays; and the annual salary or wage rate of each employee. While not all of these data were specifically necessary for preparing operation and maintenance cost estimates, they were obtained to permit the development of manpower requirements.

A breakdown of annual labor costs was obtained to determine direct labor costs and fringe benefits provided plant employees. Material and supplies, including chemicals, and electric power or fuel costs were related to the individual plant components, where possible.

In addition to data collected from field investigations, data were also available for this study from annual operating reports of wastewater utilities on file at the Robert A. Taft Water Research Center, Environmental Protection Agency, Cincinnati, Ohio, and Black & Veatch files. Most of these reports did not present cost data in sufficient detail to be of significant value to the study, although many reports did present some plant staffing and/or fringe benefit information.

Wastewater treatment plants investigated as a basis for operating cost data experience cover a broad geographical area, and are representative of varied operating conditions. Cost data have been adjusted to reflect estimated cost levels as of January 1971.

TABLE 2

WASTEWATER TREATMENT PLANTS INVESTIGATED

Location of Plants	Name of Plant[a]	Design Capacity[b] mgd	Type of Treatment		
				Secondary	
			Primary Only	Trickling Filters	Activated Sludge
California:					
Sacramento	Main Plant	72	*		
San Jose		94			*
Florida:					
Miami	Virginia Key	47			*
Illinois:					
Bloom Township[c]		8.5			*
Springfield[c]		16			*
Indiana:					
Shelbyville		2.8		*	
Kansas:					
Johnson County	Indian Creek	17.5		*	
Topeka		20			*
Wichita	Plant Nos. 1 & 2	35		*	
Michigan:					
Midland		6.5		*	
Warren		36			*
Missouri:					
Joplin	Shoal Creek	4		*	
	Turkey Creek	12		*	
Kansas City	Eastside Complex	85	*		
Monett		1		*	
St. Louis	Coldwater	25			*
Springfield	Northwest	3			*
	Southwest	12			*
Ohio:					
Wooster		5.3			*
Oklahoma:					
Tulsa	Northside	11		*	
	Southside	20	*		
Pennsylvania:					
Allegheny County[c]		150	*		
Rhode Island:					
Providence		60			*

a - Identifies the plant investigated in locations where more than one plant is operated by the city, district, or authority.

b - The capacity of the plants at the time the field investigations were conducted.

c - Sanitary district or authority.

mgd - million gallons per day

The estimated relationships of operation and maintenance cost items to appropriate parameters presented are based principally upon graphical analysis of experience data. It should be realized that it is not possible to recognize all variations in operation and maintenance procedures occurring among individual operating plants. Therefore, significant judgment has been exercised by the investigators in the establishment of curves designating cost relationships. The resulting curves represent the investigators' judgment as to average cost data.

Based upon variations in experienced operating cost data, it is estimated that specific data for individual components in particular situations will vary widely, often 100 per cent or more from the average represented by the curves. These variations can result from such factors as differences in plant design, operating procedures, safety policies, training programs, and flexibility in the use of personnel. The percentage variations in operating costs at plants comprised of several components may be less than indicated for individual components, due to the tendency for composite estimates to vary less than individual components.

While actual costs may vary appreciably from estimated average costs, data presented in this report should be of value, when used with judgment, as basic indicators for preliminary cost estimates. The user should recognize the inherent limitations of such estimates, and should develop applicable operating cost estimates as warranted by local circumstances.

Data for estimating operation and maintenance costs of each of the major components of wastewater treatment plants include annual payroll man-hours for operating labor, annual payroll man-hours for maintenance labor, and annual costs of materials and supplies. The principal plant components to which each of these items is related are as follows:

1. Wastewater Pumping
2. Preliminary Treatment
3. Sedimentation
4. Trickling Filters
5. Aeration - Diffused Air System
6. Aeration - Mechanical Aerators
7. Chlorination
8. Primary Sludge Pumping
9. Sludge Holding Tanks
10. Sludge Digestion
11. Sludge Drying Beds
12. Sludge Lagoons
13. Vacuum Filtration
14. Centrifugation
15. Incineration
16. Yard Work
17. Laboratory
18. Administration and General

A basis is also provided for estimating indirect labor costs paid by the utility, such as social security; contributions to pension, retirement or welfare funds; and premiums paid for hospitalization, health, life and workmen's compensation insurance.

Following the presentation of cost relationships for the 18 components of conventional wastewater treatment plants, a calculation summary form and example application are presented as illustrations of their use.

SECTION II

ESTIMATES OF OPERATION AND MAINTENANCE REQUIREMENTS

Data are presented in this section of the report to serve as a basis for operation and maintenance cost estimates of components of conventional wastewater treatment facilities.

To permit adaptation of estimating data to local conditions, labor requirements for both operation and maintenance are presented in the form of payroll man-hours required versus appropriate capacity or use parameters, rather than direct dollar costs. This will permit application of current local labor rates to the estimated man-hour requirements in developing labor cost estimates for any particular local situation.

Material and supply costs, including power, fuel, and chemicals, in annual dollars required are presented as a direct relationship to averages for cost levels as of January 1971. To reflect changes in these costs in later periods, they may be trended to the applicable date by using the "Wholesale Prices and Price Indexes" as published by the Bureau of Labor Statistics, U. S. Department of Labor. The indexes for recent months are shown in that publication in the table entitled "Wholesale Price Indexes for Major Commodity Groups", under the heading "Industrial Commodities". The index for January 1971 is 112.2. In trending, if knowledge of a specific local situation indicates a more appropriate trend, such information should be utilized.

The annual labor requirements, in payroll man-hours and material and supply costs, including power, fuel, and chemicals are related, where appropriate, to the same sizing parameters used for construction costs in Part One of this report for respective plant components. In certain instances a different parameter is more appropriate to operation and maintenance cost relationships than the one used for construction costs.

The annual payroll man-hours for operation and maintenance, respectively, are indicative of the total requirement for personnel to adequately operate and maintain the facility. Man-hour requirements are based on a normal payroll year consisting of 52 weeks at 40 hours per week, or a total of 2,080 hours per year. Effective working time is estimated to be 90 per cent of the payroll man-hours, with the remaining 10 per cent representing paid vacations, holidays, sick time and other paid time away from the job. While normally full-time employees are anticipated, the payroll man-hours may include a suitable combination of part-time employees.

It must be recognized that the estimates of payroll man-hour requirements shown are only representative of requirements. They are a valid basis for the cost estimate only if the man-hours required can be obtained efficiently, with any balance of an employee's time

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available to be used effectively elsewhere. Normally, several component parts of a plant will be operated together, making possible an efficient use of an individual employee's time.

Material and supply costs presented herein include allowances for contract maintenance work. The degree to which such work is accomplished by contractors rather than plant personnel will affect requirements for both maintenance payroll man-hours and the allowance for material and supply costs. Prevailing normal practice in the degree of contract work is reflected in estimating data presented.

In Part Three of this report a method of developing a practical staff complement on the basis of estimated payroll man-hours is provided.

WASTEWATER PUMPING

Operation and maintenance cost data, as presented herein, are applicable to raw wastewater pumping, intermediate pumping, or recirculation pumping.

Operation and maintenance labor requirements for wastewater pumping stations can vary widely from one station to another, depending on the type of pumping equipment installed, the degree of station automation, and the amount of auxiliary equipment installed. While some differences in labor requirements can also occur between raw wastewater, intermediate, and recirculation pumping, for purposes of this report the estimated requirements are considered to be similar.

Maximum flow capacity is a principal factor affecting labor costs for pumping facilities and is used as the parameter to which pumping station operation and maintenance labor is related. Figure 26, Page 83, shows the estimated annual payroll man-hours required for operation labor and maintenance labor, respectively, for wastewater pumping in relation to the firm pumping capacity of the station. Annual payroll man-hours for operation labor for a particular capacity pumping station are indicative of the total number of personnel required to adequately operate the facility. For example, for a pumping station with a firm pumping capacity of 20 mgd, the estimated operation labor requirement is approximately 800 man-hours per year, and the estimated maintenance labor requirement is approximately 660 man-hours per year.

Material and supply costs, particularly electric power costs for pumping, are principally related to the average quantity of wastewater pumped. Figure 27, Page 84, shows estimated annual material and supply costs related to the average quantity of wastewater pumped, expressed in million gallons per day. Estimated electric power costs, which have been separated from other material and supply costs, are based on a total pumping head of 30 feet and unit power costs varying from 1.5 cents per kWh for flows less than 4 mgd to 1.0 cent per kWh for flows greater than 4 mgd. If the total pumping head or unit power cost in a specific situation varies significantly from these values, the estimated power cost should be adjusted accordingly.

PRELIMINARY TREATMENT

Preliminary treatment, as described in Part One of this report, refers to grit removal, screening, grinding and flow measurement. Operation and maintenance costs can vary widely, from plants with facilities relatively simple to operate and maintain, such as those having hand cleaned bar screens and hand cleaned channel type grit chambers, to plants with a considerable amount of mechanical equipment for screening, grinding, and grit removal.

Operating labor requirements of these facilities will depend upon the amount of grit to be removed from the grit chamber. Much more grit can be expected at plants serving combined storm and sanitary sewer systems than at plants serving only sanitary systems. The type of screening equipment utilized will also affect operating costs.

Maintenance labor requirements of these facilities will depend principally on the amount and kind of mechanical equipment installed at the screening, grinding, and grit removal facilities. Maintenance will also be greater if the grit chamber is aerated, due to maintenance of the diffusers and air supply equipment.

Labor requirements and material and supply costs are principally related to the quantity of wastewater entering the treatment plant.

Figure 28, Page 85 , shows the estimated annual payroll man-hours required for operation labor and maintenance labor, respectively, for preliminary treatment facilities, as related to the average plant flow. Figure 29, Page 86 , shows the estimated annual material and supply costs related to the average plant flow.

SEDIMENTATION

Labor requirements and material and supply costs related to sedimentation basins are principally dependent upon the size and type of sludge and scum collection equipment used. Equipment size is essentially based on basin surface area. Therefore, surface area is the most suitable single parameter for cost estimating.

Figure 30, Page 87 , shows the estimated relationship of annual labor requirements to the surface area of the basins.

The major items of material and supply costs for sedimentation facilities generally are the material costs for repair of sludge collection mechanisms, and for painting or coating metal surfaces, including weirs. Figure 31, Page 88 , shows estimated material and supply costs for sedimentation facilities.

The labor and cost requirements for both primary and secondary sedimentation are sufficiently similar to permit use of Figures 30 and 31 in developing estimates for either type of facility.

TRICKLING FILTERS

Operation and maintenance labor for trickling filters is required to check and maintain distributor equipment, prevent underdrain clogging, and to clear the rock surface of foreign material. In severe winter climates the distributor must be kept clear of ice accumulations.

The principal efforts required in operating and maintaining trickling filters are related to the magnitude of filter surface. Therefore, filter surface area is the most suitable cost parameter and is used in this report for estimating labor requirements and material and supply costs.

Figure 32, Page 89, shows the estimated labor requirements for operation and maintenance of trickling filters. Figure 33, Page 90, shows estimated material and supply costs for these facilities.

AERATION

Aeration facilities commonly used in current practice for the activated sludge treatment process include diffused air systems, mechanical aerators, or a combination of the two. Operation and maintenance labor requirements, and material and supply costs, are developed for both types of aeration facilities.

Considerable operating man-hours are required to properly operate aeration facilities and obtain the high degree of treatment of which this process is capable. The basic objectives in operating the activated sludge process include the maintenance of an adequate quantity of dissolved oxygen in the aeration basins to develop an activated sludge which will readily separate from the treated wastewater in final settling basins.

Maintenance labor is required to keep the equipment and structures in good operating condition. When a diffused air system is used this will include care of blowers and drive units, air filters, blower building, air supply piping, air diffusers, aeration basins, and electric control equipment. When mechanical aerators are used, maintenance labor is required to keep the equipment, consisting of the aerator units and associated controls, and the aeration basins in proper operating condition.

Figure 34, Page 91, shows the estimated operation and maintenance labor requirements for diffused air systems related to firm blower capacity. Figure 35, Page 92, shows the estimated labor requirements for mechanical aerators.

Material and supply cost estimates applicable to both diffused air systems and mechanical aerators are shown on Figure 36, Page 93. The electric power costs, separated from other material and supply costs because of their relative magnitude, are based on unit power costs varying from 1.3 cents per kWh for flows less than 4 mgd to 1.0 cent per kWh for flows greater than 4 mgd. If the unit power cost in a specific situation varies significantly from these values, the estimated power cost should be adjusted accordingly.

Costs shown on Figure 36 are related to the average plant flow. The quantity of recirculated waste should not be included in the use of these estimating curves.

It is recognized that alternate sources of energy, such as internal combustion engines, may be used for operation of aeration equipment, but the electric power costs shown are considered representative of power costs incurred in operating the equipment.

CHLORINATION

Chlorine is added to wastewater during the treatment process as an aid to treatment and for disinfection. The annual consumption of chlorine at wastewater treatment plants can vary greatly depending on the quantity and quality of wastewater treated, whether the chlorine is used during warm months only or on a year round basis, and the number of locations where chlorine is added in the treatment process.

Operating labor for chlorination facilities provides for regular checks on the rate of chlorine use and adjustments of the feed rate when required. As larger quantities of chlorine are used, the need for periodic checks becomes more important to avoid undue costs resulting from excess feed rates and to assure adequate feed. Operating labor also replaces empty chlorine tanks. Maintenance labor repairs and maintains all chlorine handling equipment and contact basins, and provides related maintenance work.

Figure 37, Page 94, shows the estimated annual operation and maintenance labor requirements for chlorination systems, related to chlorine use. Figure 38, Page 95, shows material and supply cost estimates for chlorination based on use. The estimated cost of chlorine is shown separately from other material and supply costs.

The cost of chlorine varies with the quantity used and the distance between the point of manufacture and the point of use. As of January, 1971 the price of chlorine generally varied from about 14 cents per pound at plants using very small quantities and where the shipping distance might be a maximum, to 3 cents per pound at plants using more than 800 tons per year and where chlorine is shipped in tank cars. This range of costs is recognized in the average chlorine cost figures shown in Figure 38.

Other material and supply costs include the materials and parts to keep the chlorination facilities in proper operating condition. It also includes the utility costs required to operate the feeders, evaporators and pumps, and to heat the building in which the facilities are located.

PRIMARY SLUDGE PUMPING

This plant component consists of the pumping equipment, controls, and structure related to pumping sludge from the primary sedimentation tanks to other plant components. Operating labor requirements vary with the degree of automation of pump control and duration of pumping cycle. Maintenance labor depends to some degree on the type of pumps used, degree of automatic control, and physical arrangement of pumps and associated equipment.

Figure 39, Page 96, shows estimated operation and maintenance labor for primary sludge pumping as related to the firm pumping capacity of the facility. Figure 40, Page 97, shows estimated material and supply costs including repair parts, pumping power and other required costs.

SLUDGE HOLDING TANKS

The labor required for operation and maintenance of sludge holding tanks varies widely, depending principally on the complexity of equipment installed. While some tanks are simply open storage basins, others may be covered and be equipped with mixing and collecting equipment.

Operating labor is required at these facilities to periodically inspect all mechanical equipment for proper operation. This equipment includes the mixing or stirring mechanism, supernatant pumps, and transfer pumps for moving sludge from the holding tanks to the sludge treatment facilities. Maintenance labor is required to periodically clean the tanks, lubricate the equipment, and maintain and repair the equipment and structures.

Figure 41, Page 98, shows estimated relationship of operation and maintenance man-hour requirements to the sludge volume or holding capacity of the tanks. Material and supply costs, shown on Figure 42, Page 99, are also related to sludge volume.

SLUDGE DIGESTION

This plant component includes the digestion tanks, control building, and equipment used in the digestion of sludge. The tanks are frequently equipped with floating covers and mixers. The associated control building usually has sludge heat exchangers, control facilities, and often includes circulation pumping equipment.

Operation labor is required to monitor and control the sludge digestion facilities. Various tests and measurements are made at these facilities and the results recorded to indicate to the operator when adjustments or changes should be made in the digestion process, including when to remove digested sludge and supernatant from the digesters. Sludge is added to digesters at frequent intervals and the proper temperature maintained by circulating the digester contents through the sludge heaters. This plant component requires proper and adequate operating labor if these facilities are to be efficiently operated.

Maintenance labor is required at digesters to clean, maintain, and repair the structures and equipment used in the sludge digestion process. Items requiring the most maintenance include floating digester covers, gas recirculation equipment, mechanical mixers, heat exchanger, pumps, control equipment, and gauges.

Figure 43, Page 100, shows the estimated annual operation and maintenance labor man-hours required for sludge digestion facilities related to the sludge volume of the digestion tanks. Figure 44, Page 101, shows estimated material and supply costs for material and parts for maintenance of the structures and equipment; electric power for pumps, blowers, and ventilation; and auxiliary fuel for heat exchangers.

SLUDGE DRYING BEDS

The principal effort required in operating sludge drying beds is for loading, hauling, and disposal of dried sludge. At smaller plants laborers hand load trucks with forks and shovels, while at larger size plants some form of mechanized equipment, such as an elevator or belt loader, is frequently utilized for loading.

Maintenance labor required to keep sludge beds in a proper operating condition includes replacing sand in the beds as needed; maintaining the sludge inlets, underdrains, cell dividers, and other structural elements of the beds; and removing weeds or other vegetation from the beds.

Figure 45, Page 102, shows the estimated labor requirements for operation and maintenance of sludge drying beds. Estimated annual man-hour requirements are related to the annual quantity of dry solids in the sludge applied to the beds.

Figure 46, Page 103, shows the estimated annual material and supply costs for drying beds. The costs are principally related to replacement of sand removed in the bed cleaning process.

SLUDGE LAGOONS

The principal factor affecting the annual labor requirements and costs of operating and maintaining sludge lagoons is the quantity of material handled during the year. The estimates presented herein are based on a sludge sufficiently low in moisture content to permit the use of mechanical excavators and landfilling of excavated material. While the work sometimes is performed in part by plant personnel, these estimates are based on sludge removal by contract.

The most suitable parameter to which cost elements can be related for purposes of preparing estimates is the annual quantity of dry solids in the sludge applied to the lagoons. Operating labor is required to check sludge condition, operate supernatant pumping facilities, and perform other routine operating tasks. Maintenance labor at sludge lagoons is required to mow the grass and maintain the roads around and between the lagoon cells, maintain the earthwork enclosing the lagoon cells, maintain pumps and pipelines used to pump supernatant from the lagoons, and other maintenance tasks.

Figure 47, Page 104, shows the estimated annual operation and maintenance labor in payroll man-hours required for sludge lagoons, based on sludge removal by contract, related to the total dry solids in the sludge applied in tons per year.

Figure 48, Page 105, shows the annual material and supply cost estimates for sludge lagoons, also related to the dry solids in the sludge applied. The principal cost involved is the contractual cost of sludge removal. Other costs include power, maintenance, and repair costs associated with the pumps and related facilities for pumping the supernatant out of the lagoons; cost of gravel or other surfacing used on the roads in the lagoon area; and the cost of chemicals for odor and weed control.

VACUUM FILTRATION

Vacuum filtration facilities, as described in Part One of this report, include the filters, auxiliary equipment, sludge conditioning chemical facilities, and the enclosing structure.

Labor requirements for operating sludge filters are principally related to size of filters and duration and frequency of filter runs, which in turn are related to the amount of material filtered. For this report the most suitable parameter for cost relationships is the total dry solids filtered in tons per year.

Operating labor requirements include filter startup time, operation of the filters, and cleanup after the filter run. Also included are operation of sludge pumping and conditioning facilities prior to treatment, conveyor operation and, where applicable, hauling of sludge to a nearby landfill. Maintenance labor includes all labor related to maintenance of sludge filters and associated facilities.

Figure 49, Page 106, shows the estimated annual operation and maintenance labor required for sludge filtration and associated facilities in relation to the tons of dry solids filtered. Operation labor is shown by two curves, one for labor required where sludge is hauled to a nearby landfill, and one for labor required where sludge is conveyed to an adjacent sludge incinerator.

The single most significant supply cost for sludge filtration is for chemicals for sludge conditioning prior to filtering. The amount of chemicals can vary depending upon the type of sludge to be filtered and the type of chemicals used. Estimates of average chemical costs have been developed and are shown on Figure 50, Page 107. Other material and supply costs, including power, filter media, repair parts, and miscellaneous supplies, are also shown on Figure 50.

CENTRIFUGATION

The estimated labor requirements for operation and maintenance of sludge centrifugation and associated facilities are shown on Figure 51, Page 108. The estimated annual payroll man-hours are related to the total annual dry solids in the sludge applied to the centrifuge. Included are labor requirements directly related to the centrifuge, sludge conditioning, and other associated facilities. Operation labor is shown by two curves, one for labor required where sludge is hauled to a nearby landfill, and one for labor required where sludge is conveyed to an adjacent sludge incinerator.

Chemical costs for sludge conditioning can vary significantly, depending on the type of sludge applied. However, the single most important cost parameter is the quantity of dry solids applied. Figure 52, Page 109, shows the estimated average cost of chemicals for sludge conditioning prior to centrifugation. Other material and supply costs, also shown on Figure 52, include maintenance and repair parts, electric power, and contractual services for periodic maintenance where such work is normally not performed by staff personnel.

INCINERATION

Labor associated with incineration facilities provides for operation and maintenance of incinerators and accessory facilities including sludge conveyors, ash handling equipment, control center, and the enclosing structures.

annual operation and maintenance labor requirements for incineration facilities are most nearly related to the quantity of dry solids incinerated. Figure 53, Page 110, shows estimated labor requirements for both operation and maintenance. Removal of ash from the incinerator building is included in the estimates. Maintenance labor includes man-hours required for proper care and repair of the incinerator and accessory equipment. Also included is the periodic repair or replacement of refractory material within the incinerator.

Material and supply costs are shown on Figure 54, Page 111. Since electric power and auxiliary fuel costs required for incinerator operations to maintain adequate temperatures are a significant part of total material and supply costs, they are separated from other costs. Other material and supply costs include repair materials, replacement of refractory, miscellaneous supplies, and contractual cost of ash removal from the plant site.

YARDWORK

Operation and maintenance of facilities included in yardwork includes all facilities at the treatment plant site outside the confines of specific structures. Included are piping, overhead and underground electrical wiring, cables, lighting, control structures, manholes, tunnels and conduits, parking, sidewalk and road paving, site landscaping, fencing and other such facilities. As a practical matter care of lawns, shrubbery, and other vegetation comprises a significant part of yard maintenance labor costs.

All labor related to these facilities is considered as maintenance in this report, and for estimating purposes may be related to the average day capacity of the plant. The man-hours required for maintenance of yard facilities is shown on Figure 55, Page 112.

Maintenance materials and supplies may also suitably be related to plant average day capacity. Estimated annual costs for this item are shown on Figure 56, Page 113.

LABORATORY

The operating labor required for laboratory work depends not only on plant size but also on the complexity of the treatment process. For example, plants with activated sludge secondary treatment processes require more laboratory control than is commonly required for primary and trickling filter plants.

Figure 57, Page 114, shows the estimated operation and maintenance labor requirements for laboratory work at treatment plants in payroll man-hours related to the plant average day capacity. Operating labor requirements shown on Figure 57 are applicable to laboratory personnel and do not include man-hours associated with collecting samples for laboratory analysis. Such samples are normally collected by other plant operating personnel. On Figure 57 estimated operating labor requirements are shown separately for activated sludge plants, and primary and trickling filter plants.

Material and supply costs related to the laboratory component include chemicals and laboratory supplies, as well as utility and miscellaneous costs associated with laboratory work. Figure 58, Page 115, shows the estimated annual material and supply costs for this component.

ADMINISTRATION AND GENERAL

Labor requirements for plant administration include all on-site personnel whose time and effort are devoted to the administration and management of the treatment plant. At small plants this might be limited to a portion of an operator's time while at large plants it would probably include several people such as the superintendent, assistant superintendent, operation and maintenance supervisors, clerk typist, and storekeeper. Figure 59, Page 116, shows the estimated payroll man-hour requirements for plant administration as related to plant average day capacity. Also shown are the estimated maintenance labor requirements. These requirements include custodial services and maintenance of administration facilities, meeting rooms and locker rooms.

General expense, other than for personnel associated with plant administration, includes material, supply, and utility costs associated with operating and maintaining administrative facilities, and other expenses required for operation and maintenance of the treatment plant which are not directly assignable to specific plant components. Such expenses typically include office supplies, communications, dues and subscriptions, office equipment repairs, travel expense, training course expense, insurance other than that related to personnel, auditing and legal services, employer furnished wearing apparel, and custodial supplies. Administrative and general expenses not related to the treatment plant function are excluded. Indirect labor costs of frin benefits sometimes considered a part of administrative and general expen are considered separately in this report. Figure 60, Page 117, shows the estimated general expense as related to plant average day capacity.

INDIRECT LABOR COSTS

The total annual labor costs of a wastewater utility consist of both direct and indirect labor costs. The direct labor costs include the salaries, wages, and other compensation actually earned by the employees. Examples of direct labor costs include base salaries or wages, overtime and premium pay, and cost of living adjustments. The base salaries or wages applicable to payroll man-hours include pay for nonworked periods such as vacation, sick leave, holidays, excused leave, and injury leave.

Indirect labor costs include those labor-related costs paid by the utility other than salaries, wages and other direct compensation. Examples of indirect labor costs include social security; contributions to pension, retirement, or welfare funds; and premiums paid on hospitalization, health, life, and workmen's compensation insurance.

Wastewater utility labor cost data from 40 cities or sanitary districts have been analyzed to determine the relationship of the indirect to the direct labor costs. The data analyzed included plants from 18 states and reflected costs experienced during 1967, 1968, and 1969. The indirect labor costs, expressed as a percentage of the direct labor costs, were generally in the 5 to 20 per cent range, averaging 13.5 per cent. It is suggested that indirect labor costs be estimated at 15 per cent of direct labor costs unless particular knowledge of a local situation indicates a more appropriate figure.

SECTION III

APPLICATION OF OPERATION AND MAINTENANCE COST ESTIMATING DATA

Table 3, Pages 79 and 80, presents a form prepared for the purpose of estimating operation and maintenance costs in any particular instance. It is assumed that the estimator has determined from preliminary design the required capacity of plant components and quantities of wastes to be treated. Based upon this premise, the total operation and maintenance cost may be estimated.

Table 3-A, Pages 81 and 82, illustrates the use of the cost data develo in this report for estimating total operation and maintenance costs. The example is based upon a hypothetical wastewater treatment plant of the activated sludge type with an average design capacity of 10 million gallons per day. The example plant provides for vacuum filtration and incineration of sludge.

The size and capacity of individual plant components and waste quantities shown for the example are representative of average conditions which may be encountered for the assumed plant. However, since variations in the relative sizes of respective components and quantities of wastes may be significant, due to differences of wastewater strengths and the overall plant design, the total cost indicated in the example may not be representative for any particular 10 mgd activated sludge plant.

The estimating form presented in Table 3 requires the application of the average local labor rate to payroll man-hours to develop estimated total direct labor costs. This labor rate may vary significantly throughout the country, and is subject to inflationary influences.

The National Average Earning Rate published by the U. S. Department of Labor, Bureau of Labor Statistics, for nonsupervisory employees in the public utility industry, under "Water, Steam, and Sanitary Systems", SIC Code 494-7, as of January 1971 is $3.68 per hour. It is estimated that inclusion of on-site supervisory personnel in the average would raise the average hourly rate to approximately $3.85. Local conditions and inflationary increases should be recognized in developing total labor cost estimates. The $4.10 per man-hour direct labor cost shown in Table 3-A is assumed applicable for the example plant.

The limitations of cost estimates based upon average conditions are again emphasized. Operation and maintenance cost data presented herein are applicable as a basis of preliminary estimates for planning requirements and methods, and for general comparative cost studies of alternative wastewater treatment methods. The data may also be applicable for use by various levels of governmental agencies in estimating the total costs of wastewater treatment facilities required to provide desired levels of treatment of all wastewater effluents in an entire area, state, region or watershed.

These data, unadjusted for particular local conditions, cannot be used for specific plant operation and maintenance cost estimates. This cost estimate source does not supplant the need for individual engineering studies of project costs.

TABLE 3

ESTIMATED ANNUAL OPERATION AND MAINTENANCE COST

Part A - Labor Costs

Project ______________; Computed By __________________; Date ____________

Cost Component	Component Parameter	Estimated Annual Payroll Man-Hour Requirements Reference Figure No.	 Operation man-hours	 Maintenance man-hours	 Total man-hours
Raw Wastewater Pumping	______ mgd firm pumping capacity	26	______	______	______
Preliminary Treatment	______ mgd average plant flow	28	______	______	______
Sedimentation - Primary	______ 1000 square feet surface area	30	______	______	______
Trickling Filters	______ 1000 square feet filter surface area	32	______	______	______
Aeration - Diffused Air System	______ 1000 cfm firm blower capacity	34	______	______	______
Aeration - Mechanical Aerators	______ horsepower total installed capacity	35	______	______	______
Sedimentation - Secondary	______ 1000 square feet surface area	30	______	______	______
Recirculation or Intermediate Pumping	______ mgd firm pumping capacity	26	______	______	______
Chlorination	______ tons per year chlorine use	37	______	______	______
Primary Sludge Pumping	______ gpm firm pumping capacity	39	______	______	______
Sludge Holding Tanks	______ 1000 cubic feet sludge volume	41	______	______	______
Sludge Digestion	______ 1000 cubic feet sludge volume	43	______	______	______
Sludge Drying Beds	______ tons per year dry solids applied	45	______	______	______
Sludge Lagoons	______ tons per year dry solids applied	47	______	______	______
Vacuum Filtration - Sludge to Landfill	______ tons per year dry solids filtered	49	______	______	______
Vacuum Filtration - Sludge to Incinerator	______ tons per year dry solids filtered	49	______	______	______
Centrifugation	______ tons per year dry solids applied	51	______	______	______
Incineration	______ tons per year dry solids incinerated	53	______	______	______
Yardwork	______ mgd plant average day capacity	55	______	______	______
Laboratory	______ mgd plant average day capacity	57	______	______	______
Administration and General	______ mgd plant average day capacity	59	______	______	______
______	______	______	______	______	______
______	______	______	______	______	______
______	______	______	______	______	______
______	______	______	______	______	______
______	______	______	______	______	______
Total Estimated Annual Payroll Man-Hour Requirements			______	______	______
Total Estimated Direct Payroll Labor Costs at $__________ per Man-Hour					$______
Estimated Indirect Labor Costs at ____% of Direct Labor Cost					$______
Total Estimated Labor Costs					$______

TABLE 3 (Cont'd)

ESTIMATED ANNUAL OPERATION AND MAINTENANCE COST

Part B - Material and Supply Costs

Project ______________; Computed By ______________; Date ______________

Cost Component	Component Parameter	Reference Figure No.	Estimated Material and Supply Costs: Power & Fuel or Chemicals $/year	Estimated Material and Supply Costs: Other $/year	Estimated Material and Supply Costs: Total $/year
Raw Wastewater Pumping	______ mgd average quantity of wastewater pumped	27			
Preliminary Treatment	______ mgd average plant flow	29			
Sedimentation - Primary	______ 1000 square feet surface area	31			
Trickling Filters	______ 1000 square feet filter surface area	33			
Aeration	______ mgd average plant flow	36			
Sedimentation - Secondary	______ 1000 square feet surface area	31			
Recirculation or Intermediate Pumping	______ mgd average quantity of wastewater pumped	27			
Chlorination	______ tons per year chlorine use	38			
Primary Sludge Pumping	______ gpm firm pumping capacity	40			
Sludge Holding Tanks	______ 1000 cubic feet sludge volume	42			
Sludge Digestion	______ 1000 cubic feet sludge volume	44			
Sludge Drying Beds	______ tons per year dry solids applied	46			
Sludge Lagoons	______ tons per year dry solids applied	48			
Vacuum Filtration	______ tons per year dry solids filtered	50			
Centrifugation	______ tons per year dry solids applied	52			
Incineration	______ tons per year dry solids incinerated	54			
Yardwork	______ mgd plant average day capacity	56			
Laboratory	______ mgd plant average day capacity	58			
Administration and General	______ mgd plant average day capacity	60			

Total Estimated Material and Supply Costs at January, 1971 Cost Level ______

Trended Total Estimated Material and Supply Costs ______% Trend Factor (See note below) ______

Total Estimated Labor Costs (from Part A) ______

Total Estimated Current Operation and Maintenance Cost ______

Note:

$$\text{Trend Factor} = \frac{\text{Wholesale Price Index for Industrial Commodities as of Applicable Date}}{\text{Wholesale Price Index for Industrial Commodities as of January, 1971}} = \frac{\_\_\_\_}{112.2} = \_\_\_\_\%$$

TABLE 3-A

ESTIMATED ANNUAL OPERATION AND MAINTENANCE COST

Part A - Labor Costs

Project Newton, Nebraska ; Computed By RWB ; Date Sept 1971

Cost Component	Component Parameter		Estimated Annual Payroll Man-Hour Requirements			
			Reference Figure No.	Operation man-hours	Maintenance man-hours	Total man-hours
Raw Wastewater Pumping	20	mgd firm pumping capacity	26	900	660	1,460
Preliminary Treatment	7.5	mgd average plant flow	28	1,500	780	2,280
Sedimentation - Primary	17	1000 square feet surface area	30	1,400	810	2,210
Trickling Filters		1000 square feet filter surface area	32			
Aeration - Diffused Air System	14	1000 cfm firm blower capacity	34	3,300	2,050	5,350
Aeration - Mechanical Aerators		horsepower total installed capacity	35			
Sedimentation - Secondary	20	1000 square feet surface area	30	1,450	860	2,310
Recirculation or Intermediate Pumping	10	mgd firm pumping capacity	26	620	530	1,150
Chlorination	115	tons per year chlorine use	37	1,250	270	1,520
Primary Sludge Pumping	180	gpm firm pumping capacity	39	1,250	540	1,790
Sludge Holding Tanks	30	1000 cubic feet sludge volume	41	730	350	1,080
Sludge Digestion		1000 cubic feet sludge volume	43			
Sludge Drying Beds		tons per year dry solids applied	45			
Sludge Lagoons		tons per year dry solids applied	47			
Vacuum Filtration - Sludge to Landfill		tons per year dry solids filtered	49			
Vacuum Filtration - Sludge to Incinerator	3,450	tons per year dry solids filtered	49	4,600	800	5,400
Centrifugation		tons per year dry solids applied	51			
Incineration	3,450	tons per year dry solids incinerated	53	3,300	1,500	4,800
Yardwork	10	mgd plant average day capacity	55	-	1,900	1,900
Laboratory	10	mgd plant average day capacity	57	1,600	240	1,840
Administration and General	10	mgd plant average day capacity	59	2,100	460	2,560
Total Estimated Annual Payroll Man-Hour Requirements				25,900	11,750	37,650
Total Estimated Direct Payroll Labor Costs at $ 4.10 per Man-Hour						$ 154,400
Estimated Indirect Labor Costs at 15 % of Direct Labor Cost						$ 23,200
Total Estimated Labor Costs						$ 177,600

TABLE 3-A (Cont'd)

ESTIMATED ANNUAL OPERATION AND MAINTENANCE COST

Part B - Material and Supply Costs

Project *Newton, Nebraska* ; Computed By *RWB* ; Date *Sept 1971*

Cost Component	Component Parameter		Reference Figure No.	Estimated Material and Supply Costs Power & Fuel or Chemicals $/year	 Other $/year	 Total $/year
Raw Wastewater Pumping	*7.5*	mgd average quantity of wastewater pumped	27	*4,000*	*1,200*	*5,200*
Preliminary Treatment	*7.5*	mgd average plant flow	29			*2,350*
Sedimentation - Primary	*17*	1000 square feet surface area	31			*2,450*
Trickling Filters		1000 square feet filter surface area	33			
Aeration	*7.5*	mgd average plant flow	36	*25,000*	*5,100*	*30,100*
Sedimentation - Secondary	*20*	1000 square feet surface area	31			*2,650*
Recirculation or Intermediate Pumping	*7.5*	mgd average quantity of wastewater pumped	27	*4,000*	*1,200*	*5,200*
Chlorination	*115*	tons per year chlorine use	38	*12,500*	*1,700*	*14,200*
Primary Sludge Pumping	*180*	gpm firm pumping capacity	40			*2,250*
Sludge Holding Tanks	*30*	1000 cubic feet sludge volume	42			*1,600*
Sludge Digestion		1000 cubic feet sludge volume	44			
Sludge Drying Beds		tons per year dry solids applied	46			
Sludge Lagoons		tons per year dry solids applied	48			
Vacuum Filtration	*3,450*	tons per year dry solids filtered	50	*27,500*	*15,000*	*42,500*
Centrifugation		tons per year dry solids applied	52			
Incineration	*3,450*	tons per year dry solids incinerated	54	*6,600*	*5,800*	*12,400*
Yardwork	*10*	mgd plant average day capacity	56			*1,800*
Laboratory	*10*	mgd plant average day capacity	58			*1,500*
Administration and General	*10*	mgd plant average day capacity	60			*4,300*

Total Estimated Material and Supply Costs at January, 1971 Cost Level *128,500*

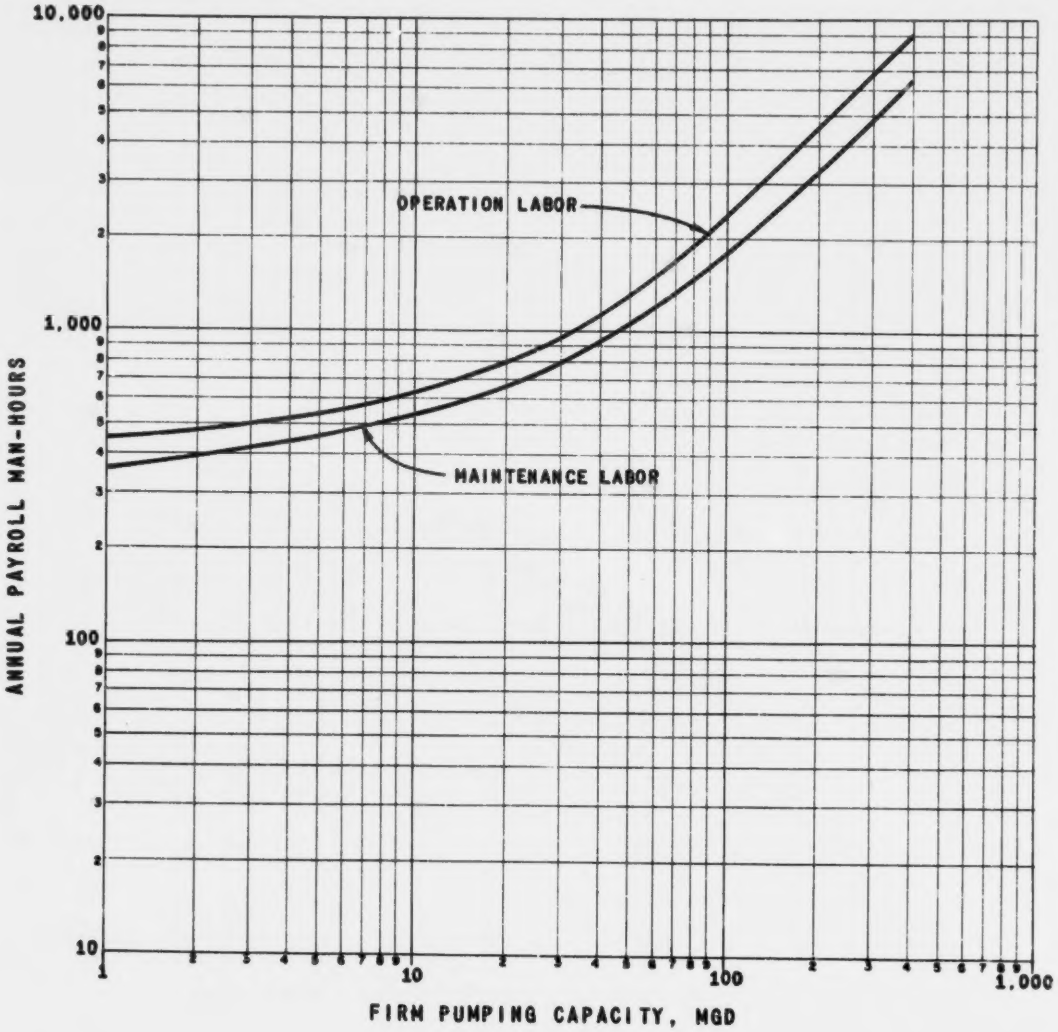
Trended Total Estimated Material and Supply Costs *102.5* % Trend Factor (See note below) *131,700*

Total Estimated Labor Costs (from Part A) *177,600*

Total Estimated Current Operation and Maintenance Cost *309,300*

Note:

$$\text{Trend Factor} = \frac{\text{Wholesale Price Index for Industrial Commodities as of Applicable Date}}{\text{Wholesale Price Index for Industrial Commodities as of January, 1971}} = \frac{115.0}{112.2} = 102.5\,\%$$



WASTEWATER PUMPING

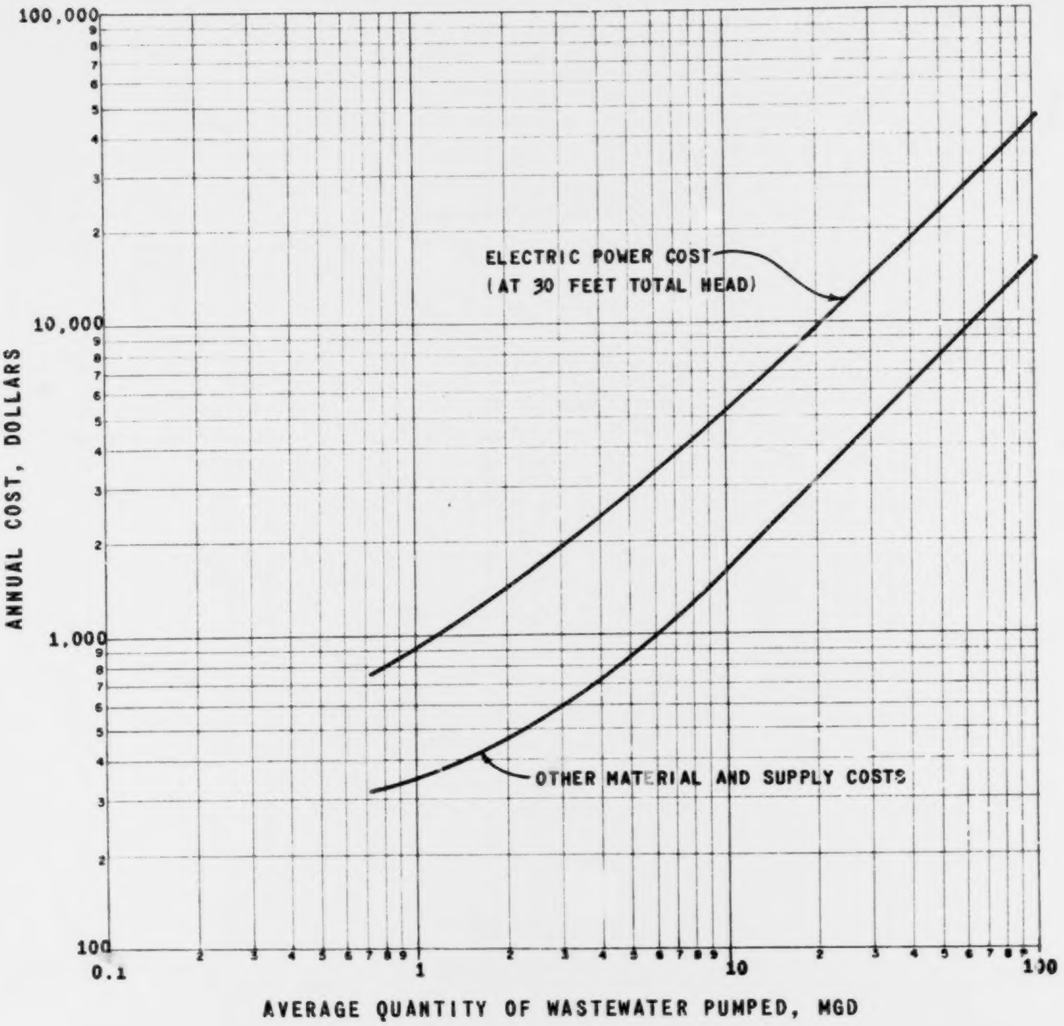
MAN-HOUR REQUIREMENTS

OPERATION AND MAINTENANCE COSTS

WATER QUALITY OFFICE
ENVIRONMENTAL PROTECTION AGENCY

BLACK & VEATCH
CONSULTING ENGINEERS
1971

FIGURE 26



WASTEWATER PUMPING

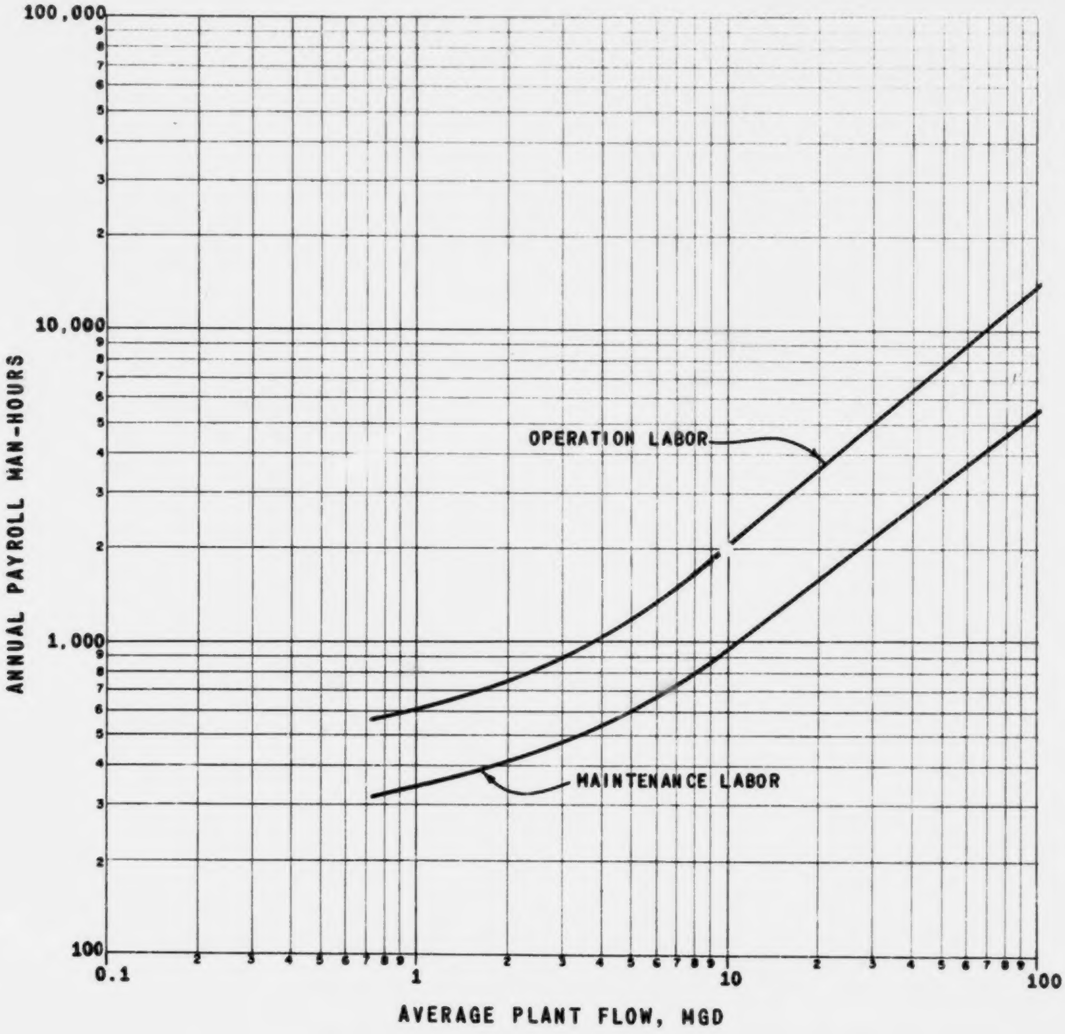
MATERIAL AND SUPPLY COSTS

OPERATION AND MAINTENANCE COSTS

WATER QUALITY OFFICE
ENVIRONMENTAL PROTECTION AGENCY

BLACK & VEATCH
CONSULTING ENGINEERS
1971

FIGURE 27



PRELIMINARY TREATMENT

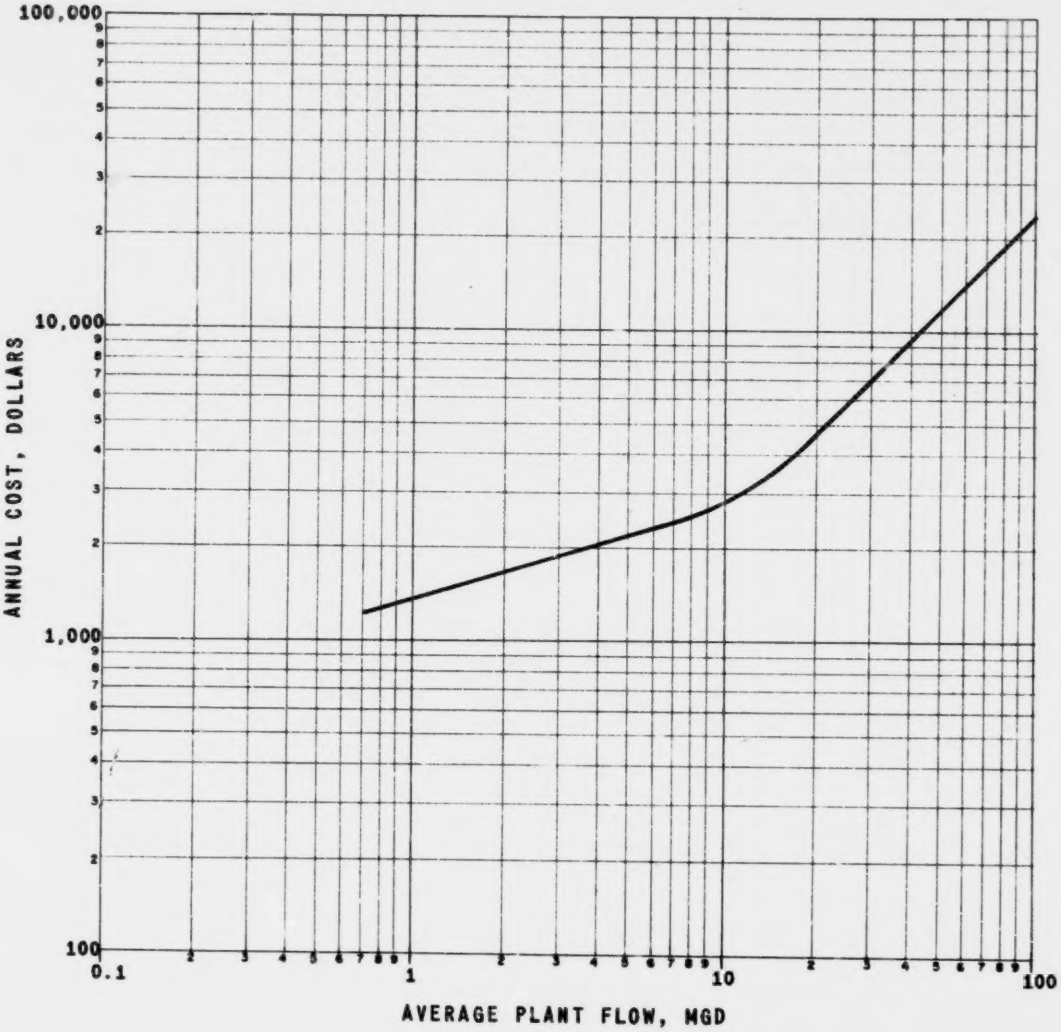
MAN-HOUR REQUIREMENTS

OPERATION AND MAINTENANCE COSTS

WATER QUALITY OFFICE
ENVIRONMENTAL PROTECTION AGENCY

BLACK & VEATCH
CONSULTING ENGINEERS
1971

FIGURE 28



PRELIMINARY TREATMENT

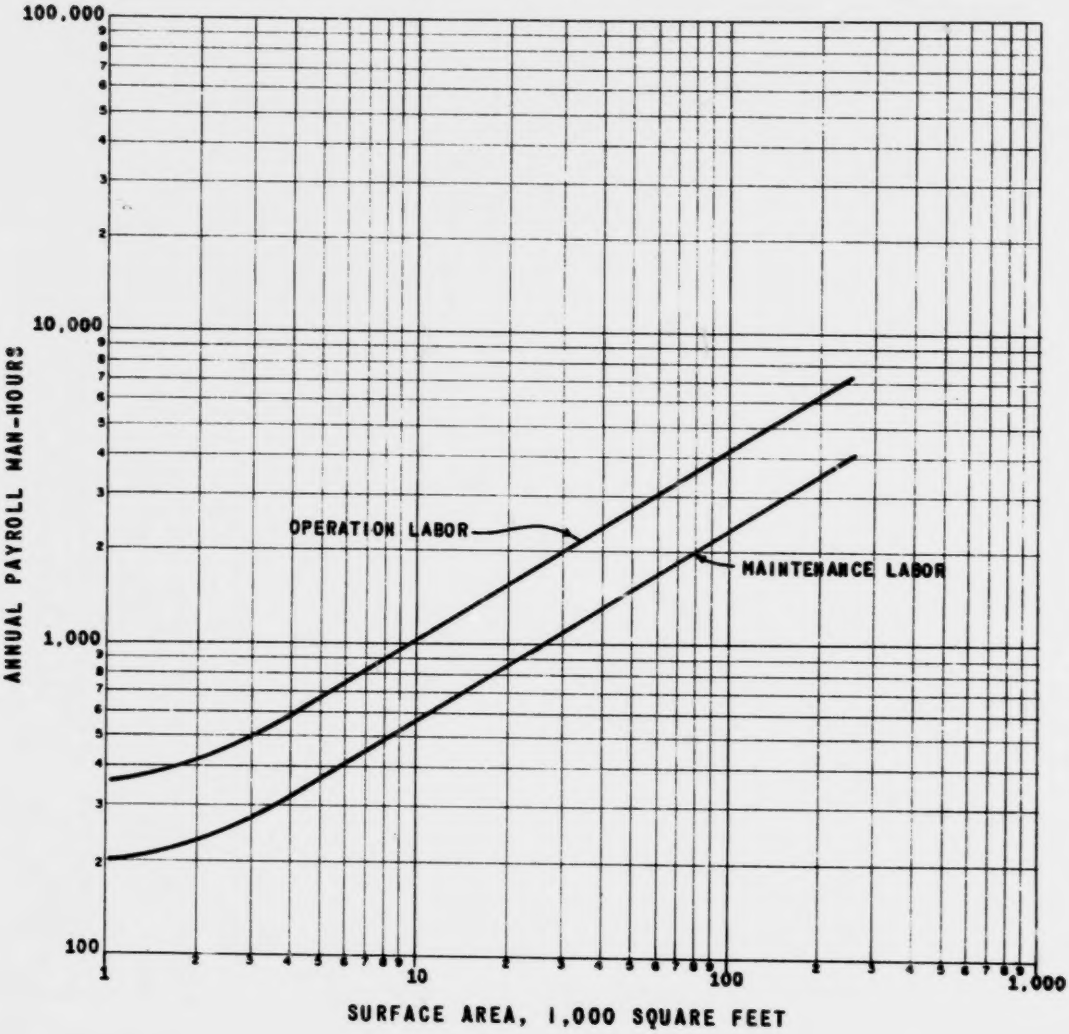
MATERIAL AND SUPPLY COSTS

OPERATION AND MAINTENANCE COSTS

WATER QUALITY OFFICE
ENVIRONMENTAL PROTECTION AGENCY

BLACK & VEATCH
CONSULTING ENGINEERS
1971

FIGURE 29



SEDIMENTATION

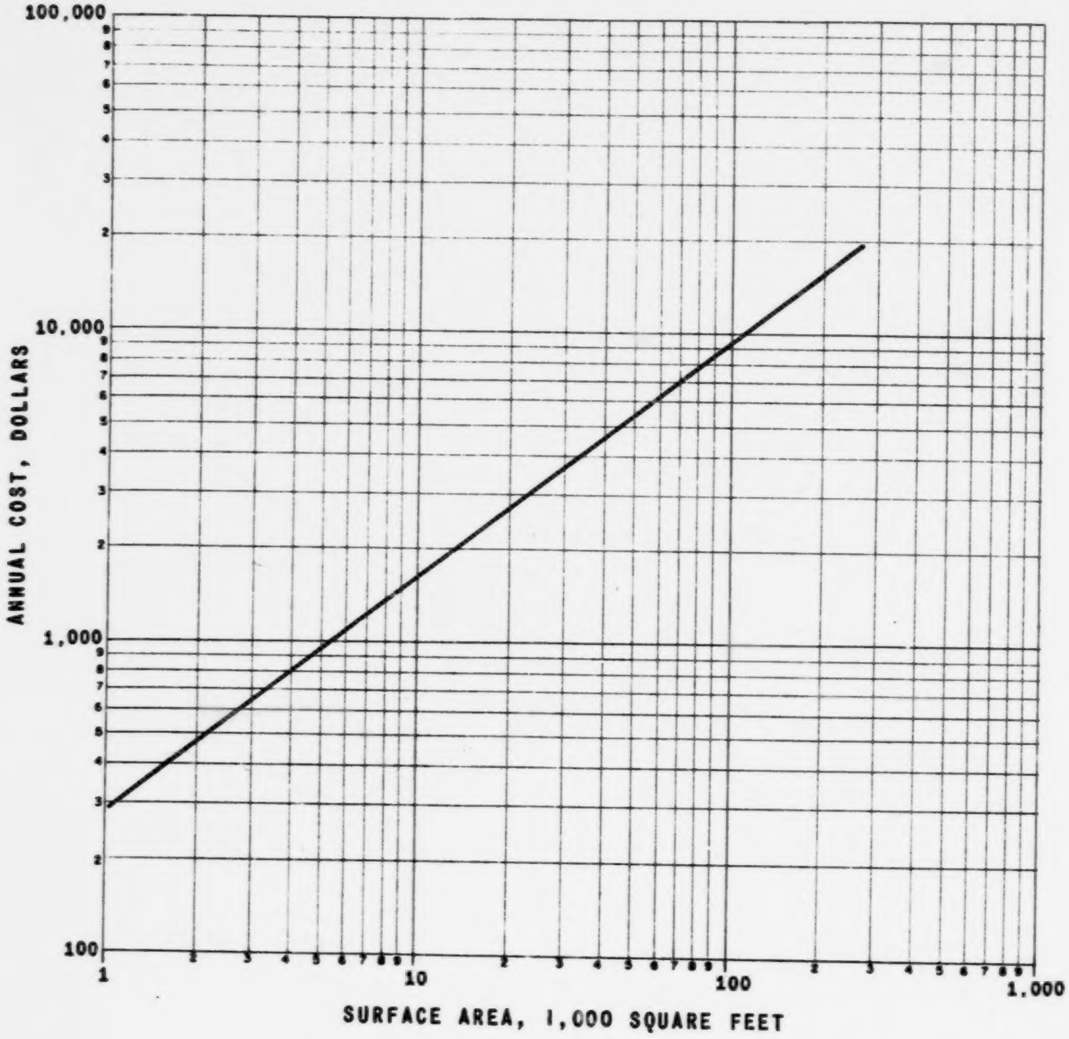
MAN-HOUR REQUIREMENTS

OPERATION AND MAINTENANCE COSTS

WATER QUALITY OFFICE
ENVIRONMENTAL PROTECTION AGENCY

BLACK & VEATCH
CONSULTING ENGINEERS
1971

FIGURE 30



SEDIMENTATION

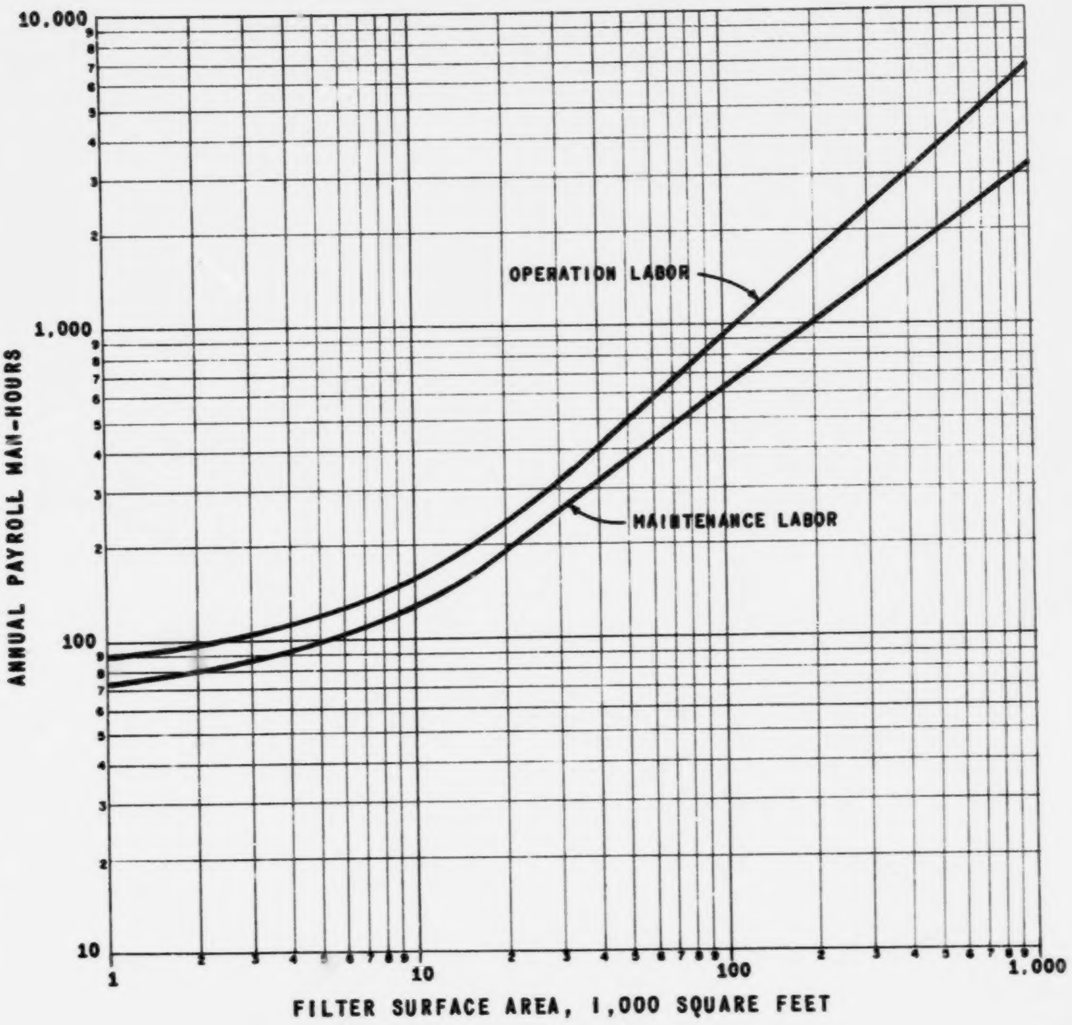
MATERIAL AND SUPPLY COSTS

OPERATION AND MAINTENANCE COSTS

WATER QUALITY OFFICE
ENVIRONMENTAL PROTECTION AGENCY

BLACK & VEATCH
CONSULTING ENGINEERS
1971

FIGURE 31



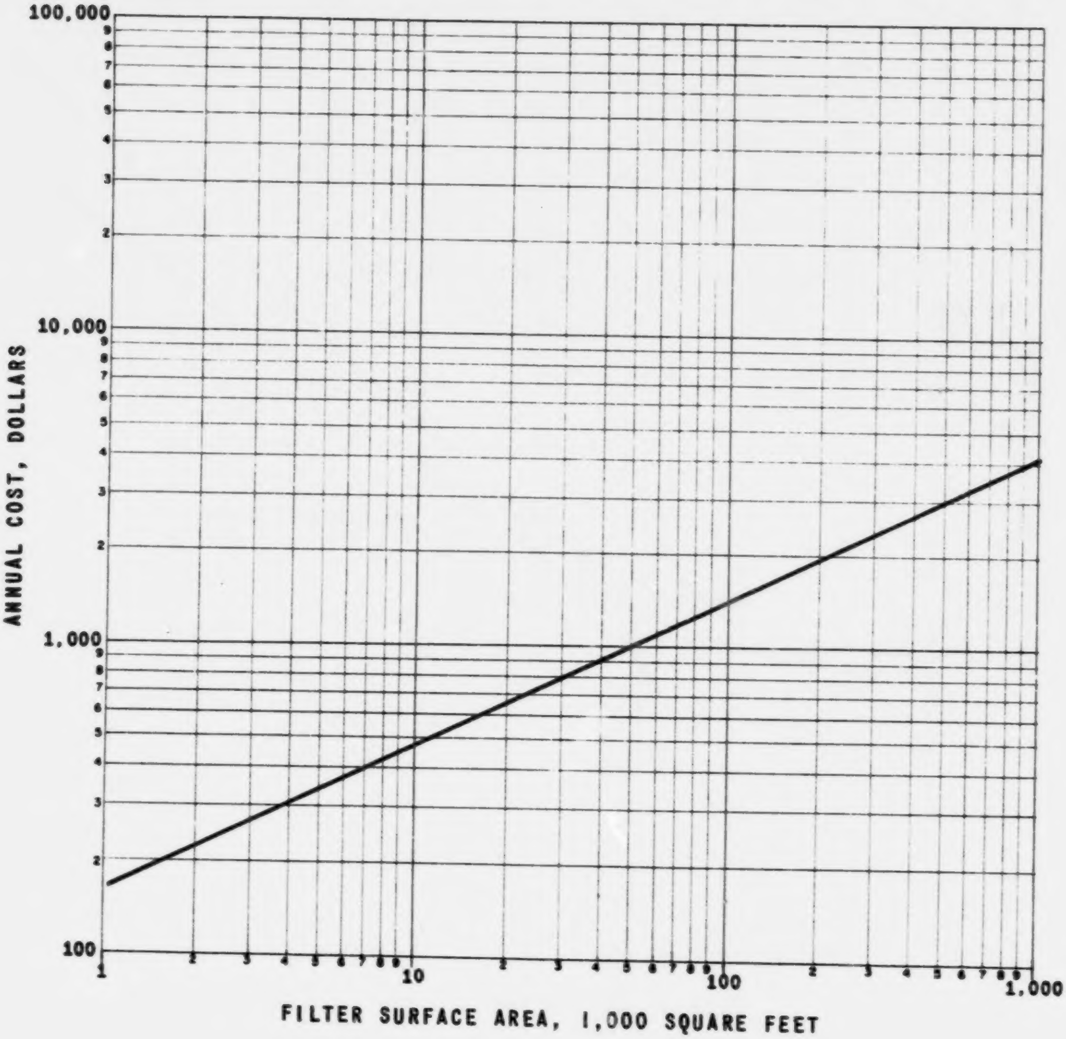
TRICKLING FILTERS
MAN-HOUR REQUIREMENTS

OPERATION AND MAINTENANCE COSTS

WATER QUALITY OFFICE
ENVIRONMENTAL PROTECTION AGENCY

BLACK & VEATCH
CONSULTING ENGINEERS
1971

FIGURE 32



TRICKLING FILTERS

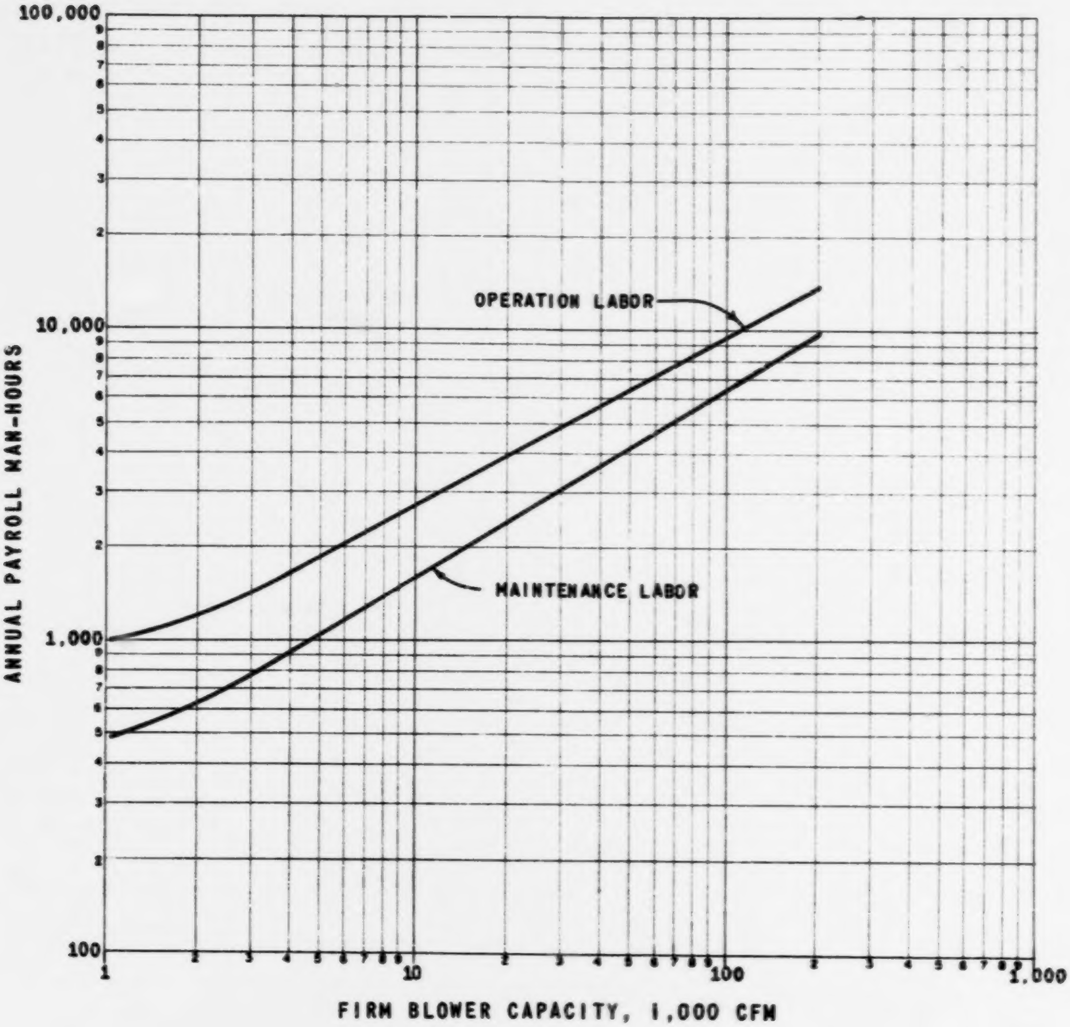
MATERIAL AND SUPPLY COSTS

OPERATION AND MAINTENANCE COSTS

WATER QUALITY OFFICE
ENVIRONMENTAL PROTECTION AGENCY

BLACK & VEATCH
CONSULTING ENGINEERS
1971

FIGURE 33



AERATION
DIFFUSED AIR SYSTEM

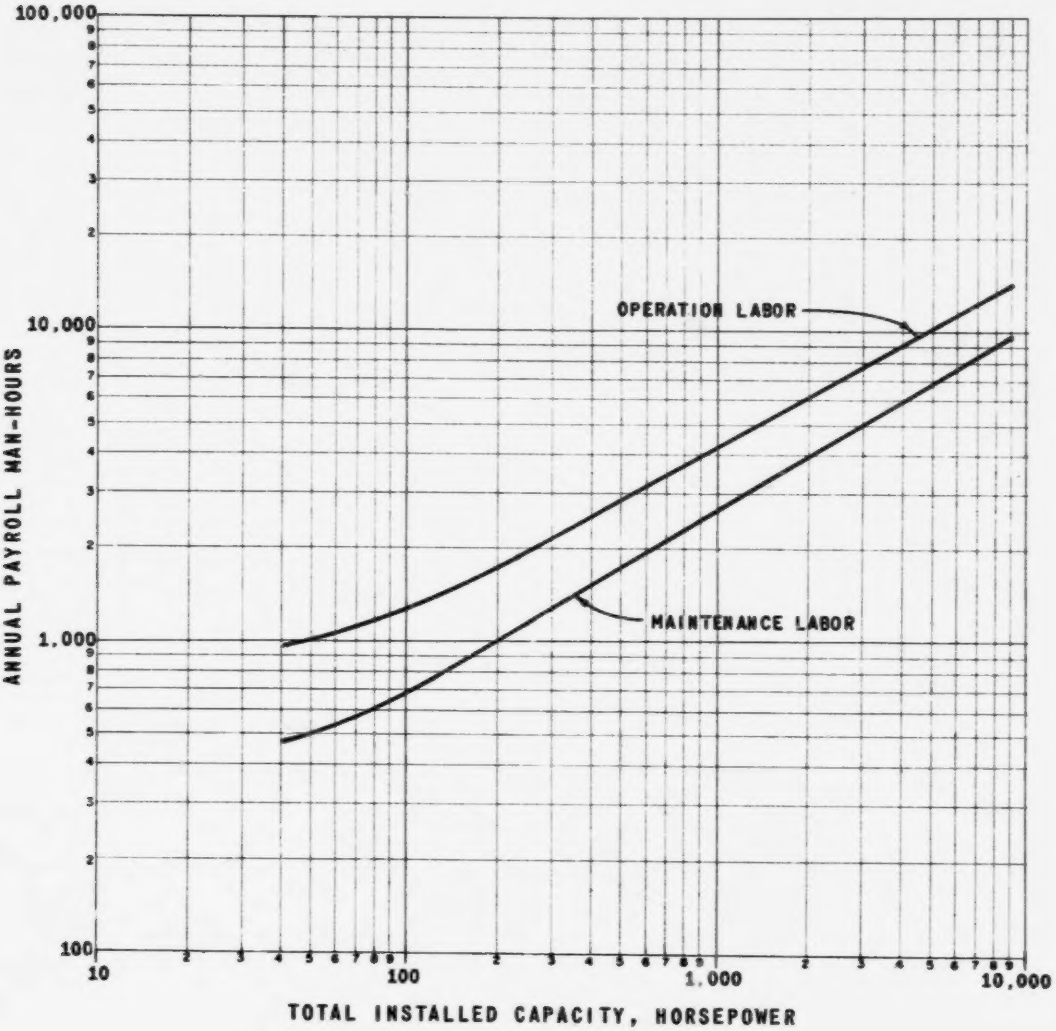
MAN-HOUR REQUIREMENTS

OPERATION AND MAINTENANCE COSTS

WATER QUALITY OFFICE
ENVIRONMENTAL PROTECTION AGENCY

BLACK & VEATCH
CONSULTING ENGINEERS
1971

FIGURE 34

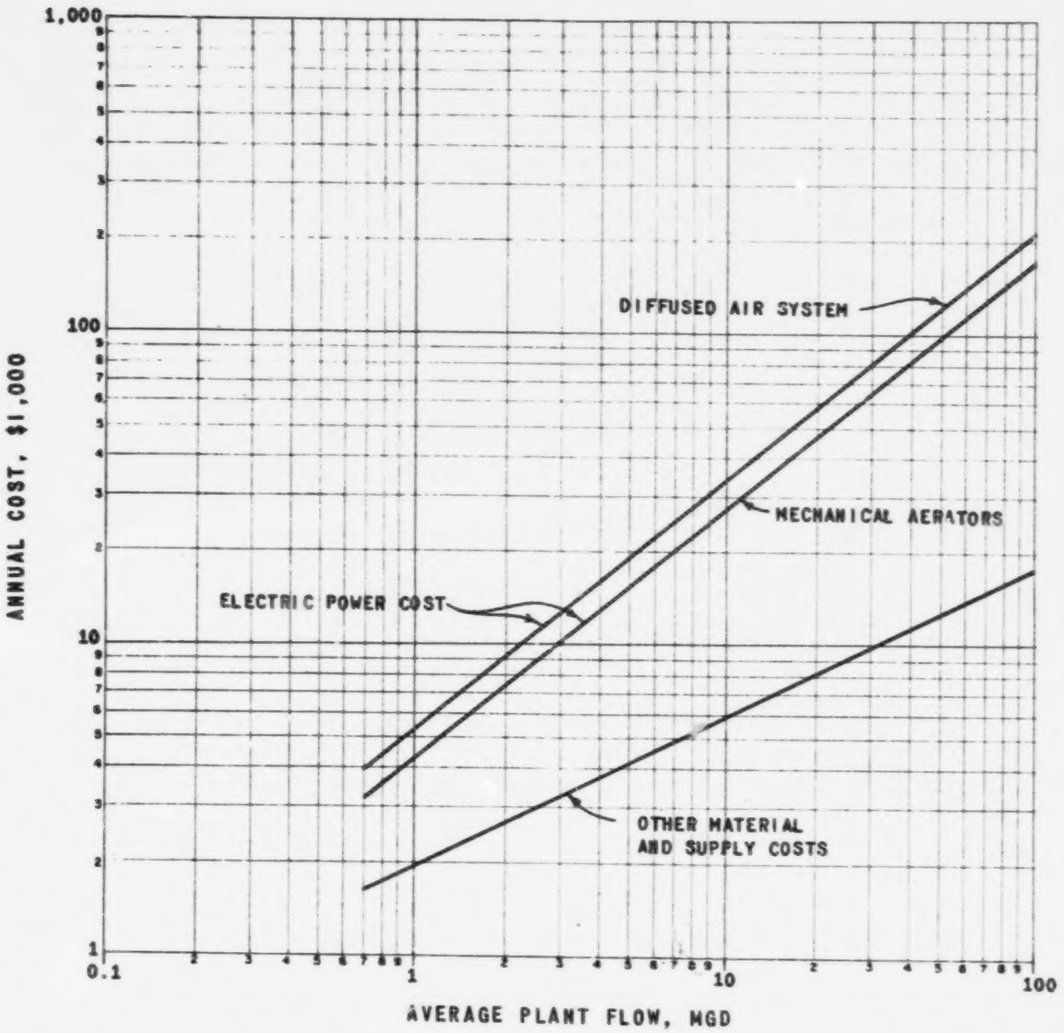


AERATION
MECHANICAL AERATORS
MAN-HOUR REQUIREMENTS
OPERATION AND MAINTENANCE COSTS

WATER QUALITY OFFICE
ENVIRONMENTAL PROTECTION AGENCY

BLACK & VEATCH
CONSULTING ENGINEERS
1971

FIGURE 35



AERATION

MATERIAL AND SUPPLY COSTS

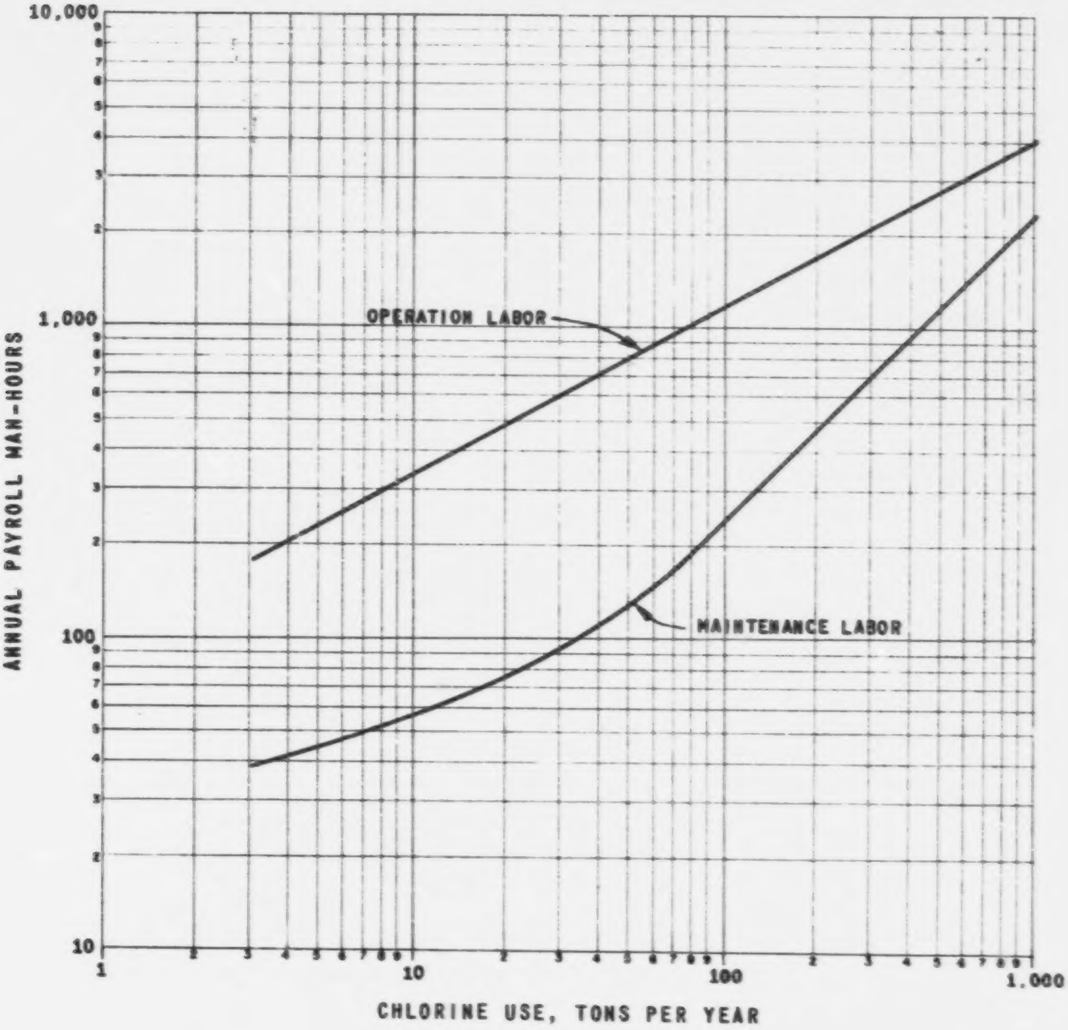
OPERATION AND MAINTENANCE COSTS

WATER QUALITY OFFICE
ENVIRONMENTAL PROTECTION AGENCY

BLACK & VEATCH
CONSULTING ENGINEERS
1971

FIGURE 36

7



CHLORINATION

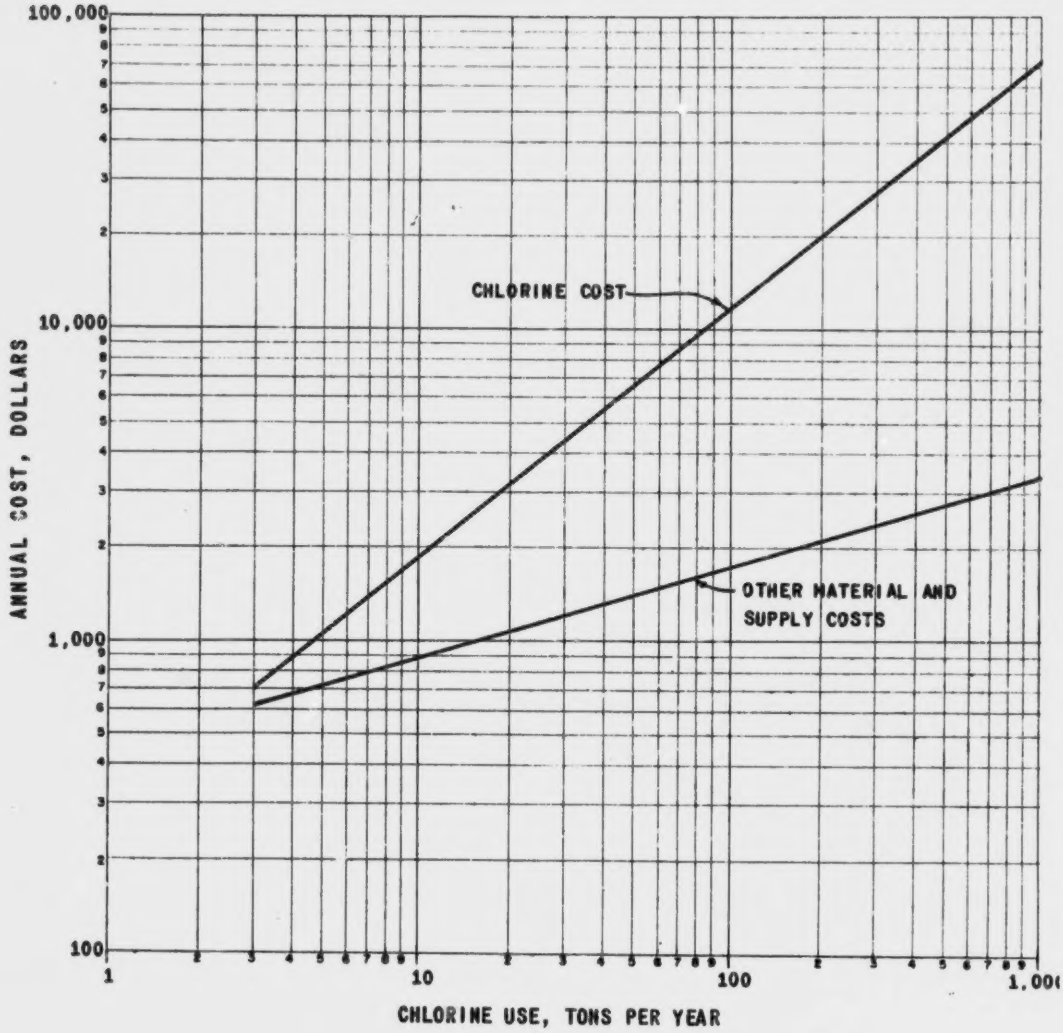
MAN-HOUR REQUIREMENTS

OPERATION AND MAINTENANCE COSTS

WATER QUALITY OFFICE
ENVIRONMENTAL PROTECTION AGENCY

BLACK & VEATCH
CONSULTING ENGINEERS
1971

FIGURE 37



CHLORINATION

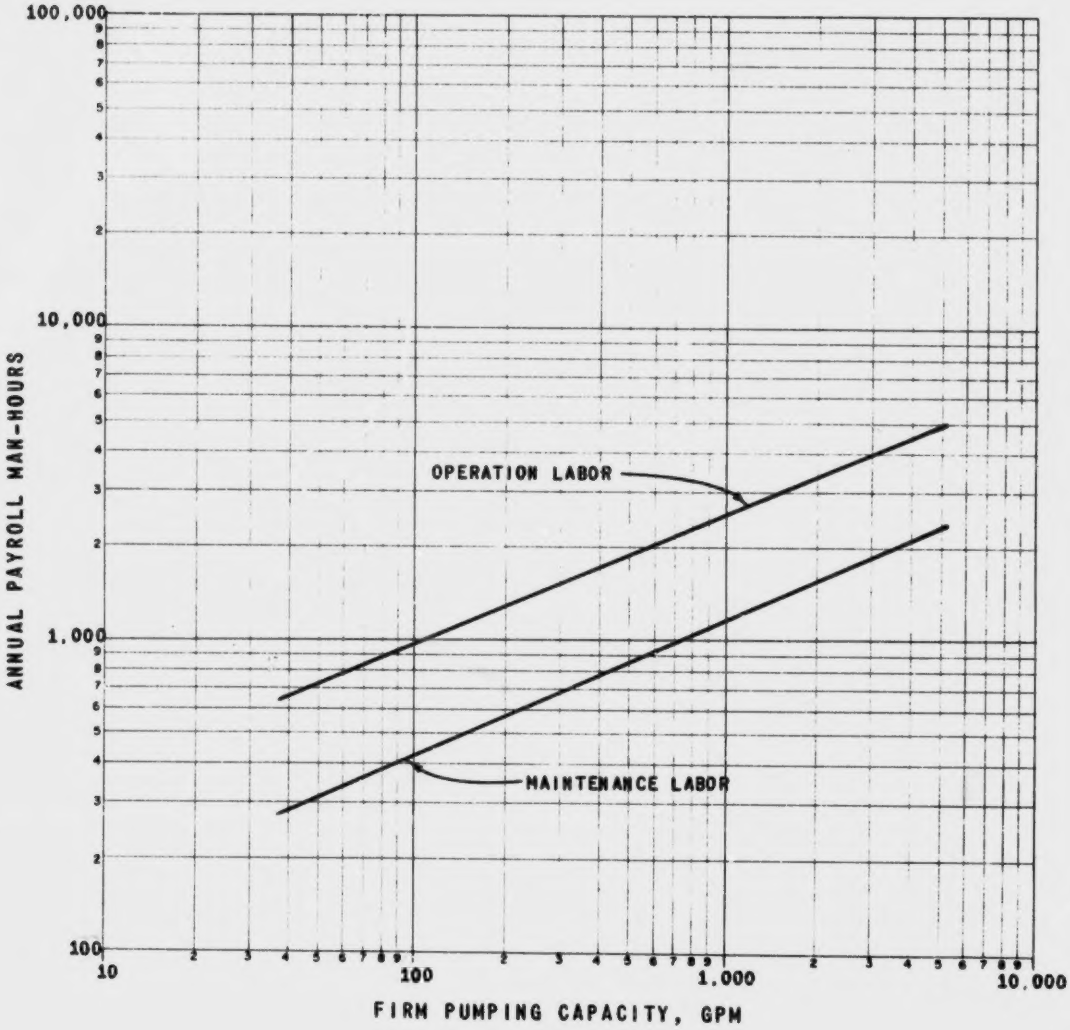
MATERIAL AND SUPPLY COSTS

OPERATION AND MAINTENANCE COSTS

WATER QUALITY OFFICE
ENVIRONMENTAL PROTECTION AGENCY

BLACK & VEATCH
CONSULTING ENGINEERS
1971

FIGURE 38



PRIMARY SLUDGE PUMPING

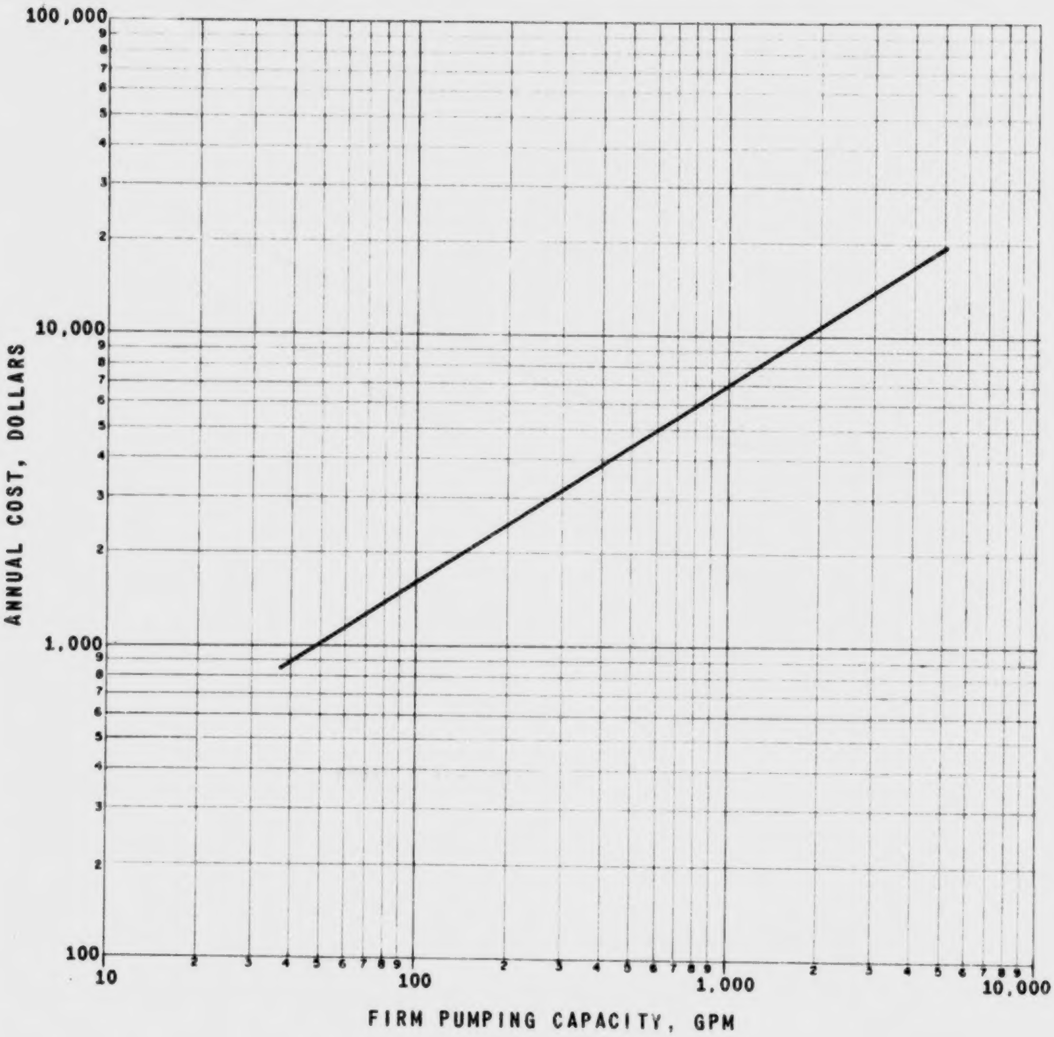
MAN-HOUR REQUIREMENTS

OPERATION AND MAINTENANCE COSTS

WATER QUALITY OFFICE
ENVIRONMENTAL PROTECTION AGENCY

BLACK & VEATCH
CONSULTING ENGINEERS
1971

FIGURE 39



PRIMARY SLUDGE PUMPING

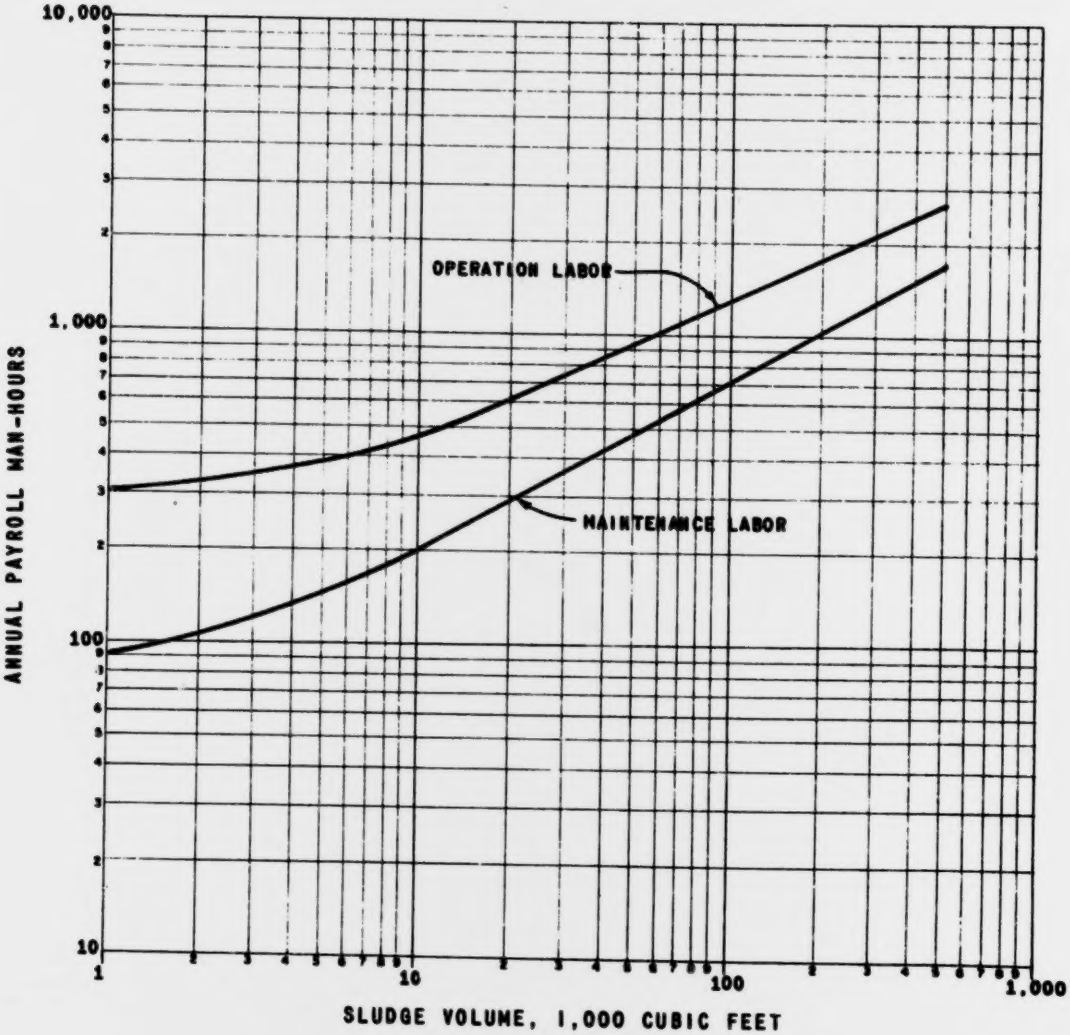
MATERIAL AND SUPPLY COSTS

OPERATION AND MAINTENANCE COSTS

WATER QUALITY OFFICE
ENVIRONMENTAL PROTECTION AGENCY

BLACK & VEATCH
CONSULTING ENGINEERS
1971

FIGURE 40



SLUDGE HOLDING TANKS

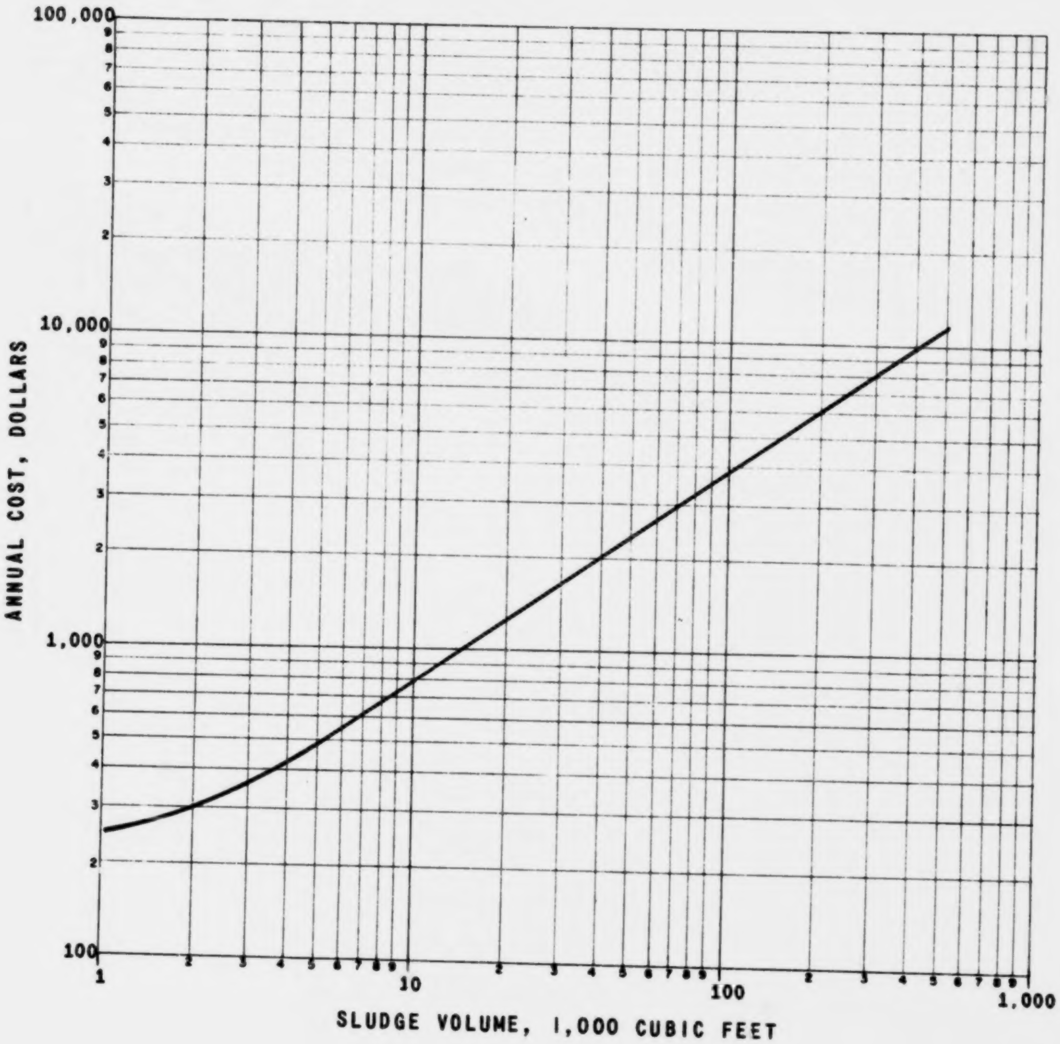
MAN-HOUR REQUIREMENTS

OPERATION AND MAINTENANCE COSTS

WATER QUALITY OFFICE
ENVIRONMENTAL PROTECTION AGENCY

BLACK & VEATCH
CONSULTING ENGINEERS
1971

FIGURE 41



SLUDGE HOLDING TANKS

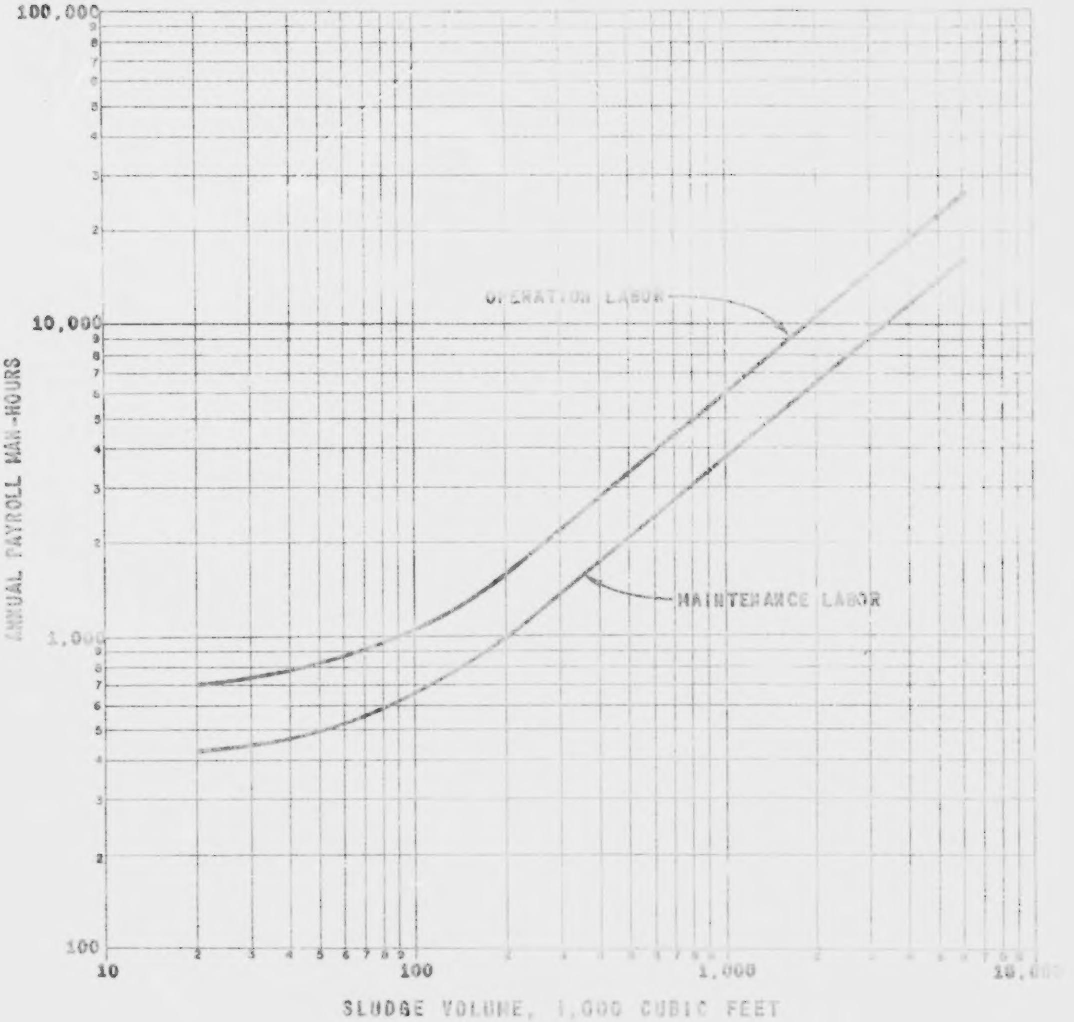
MATERIAL AND SUPPLY COSTS

OPERATION AND MAINTENANCE COSTS

WATER QUALITY OFFICE
ENVIRONMENTAL PROTECTION AGENCY

BLACK & VEATCH
CONSULTING ENGINEERS
1971

FIGURE 42



SLUDGE DIGESTION

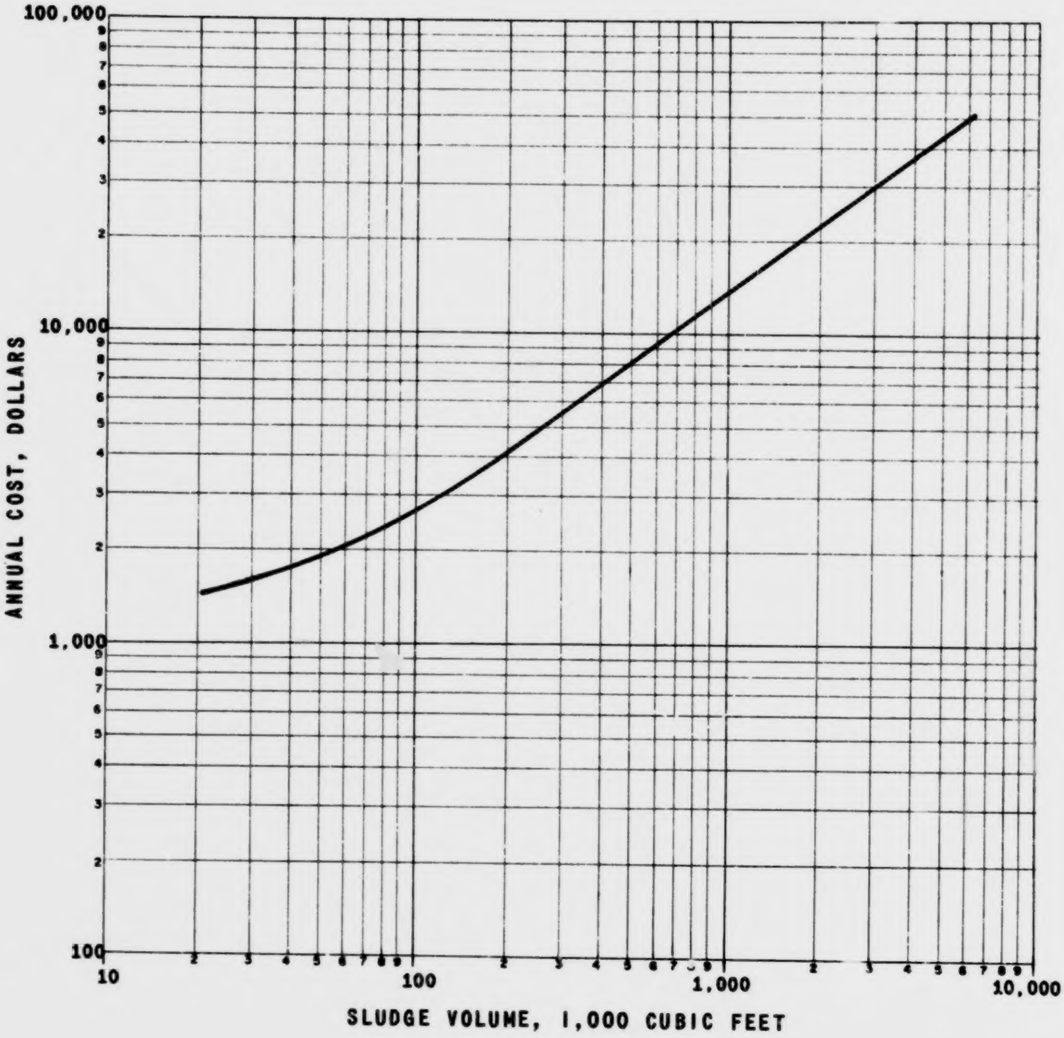
MAN-HOUR REQUIREMENTS

OPERATION AND MAINTENANCE COSTS

WATER QUALITY OFFICE
ENVIRONMENTAL PROTECTION AGENCY

BLACK & VEATCH
CONSULTING ENGINEERS
1971

FIGURE [illegible]



SLUDGE DIGESTION

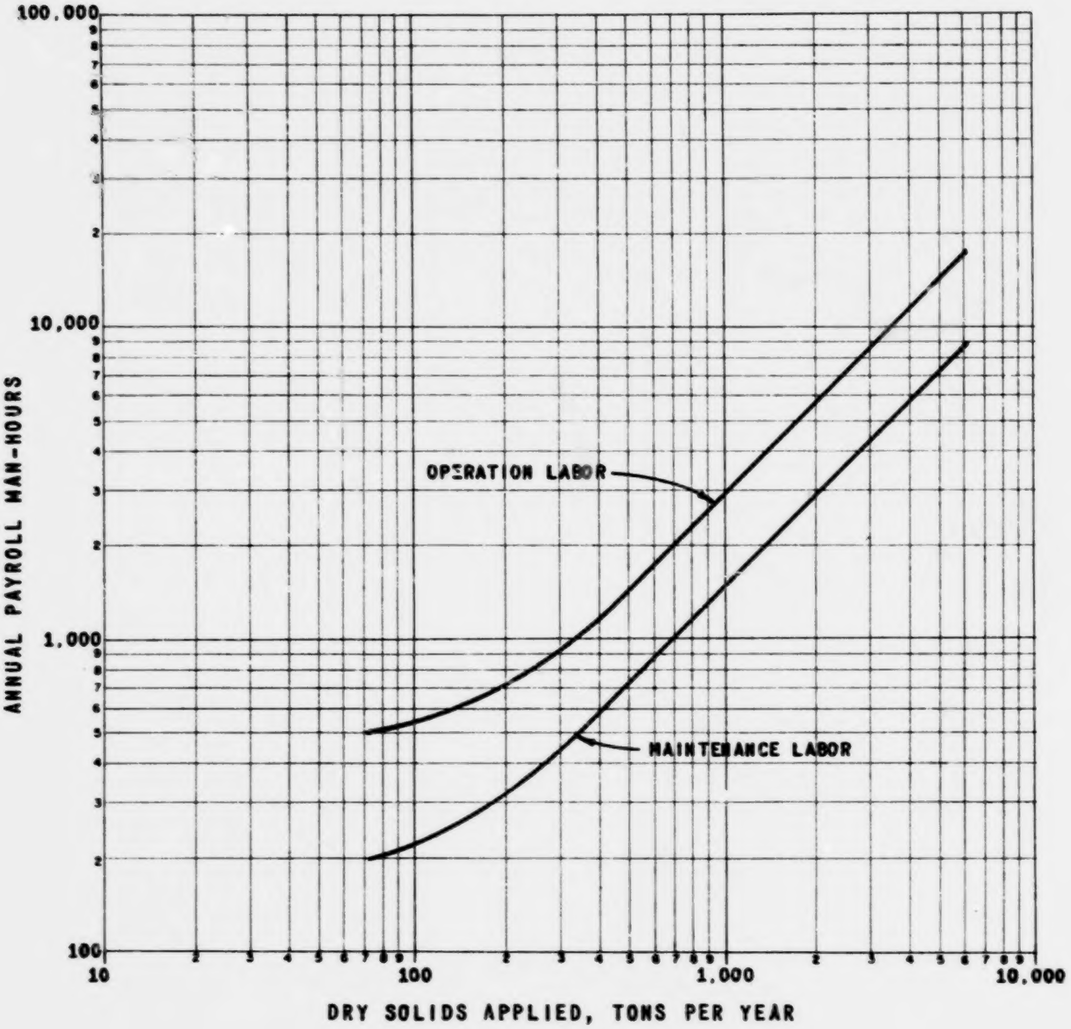
MATERIAL AND SUPPLY COSTS

OPERATION AND MAINTENANCE COSTS

WATER QUALITY OFFICE
ENVIRONMENTAL PROTECTION AGENCY

BLACK & VEATCH
CONSULTING ENGINEERS
1971

FIGURE 44



SLUDGE DRYING BEDS

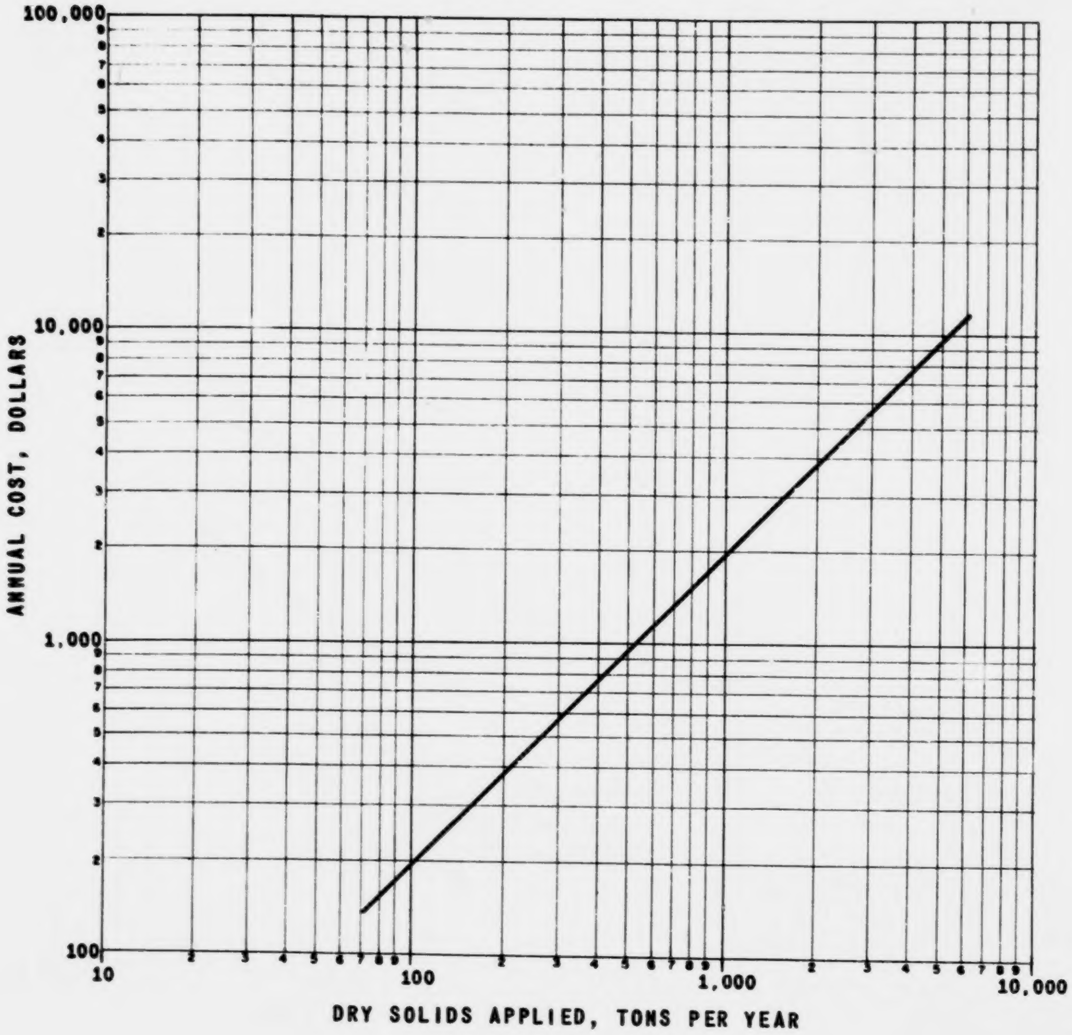
MAN-HOUR REQUIREMENTS

OPERATION AND MAINTENANCE COSTS

WATER QUALITY OFFICE
ENVIRONMENTAL PROTECTION AGENCY

BLACK & VEATCH
CONSULTING ENGINEERS
1971

FIGURE 45



SLUDGE DRYING BEDS

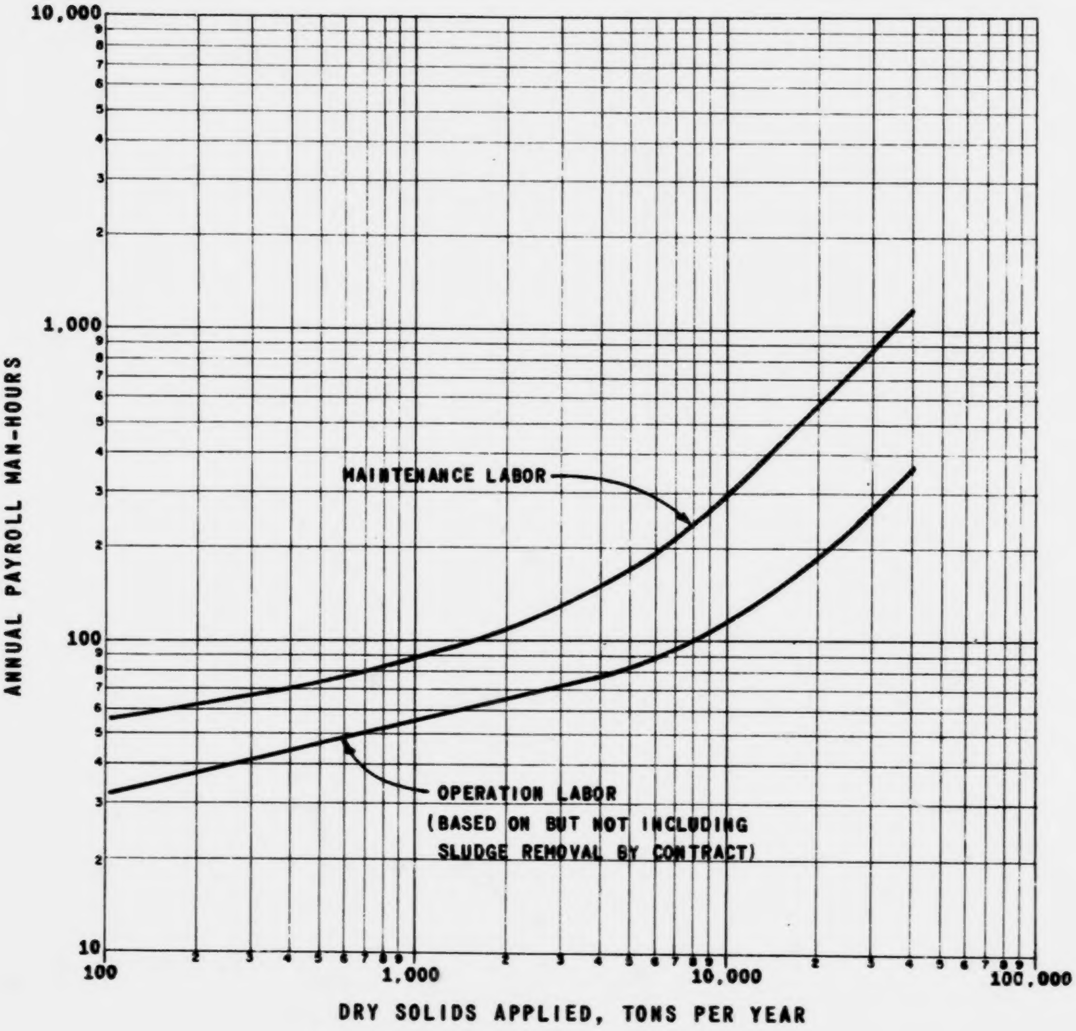
MATERIAL AND SUPPLY COSTS

OPERATION AND MAINTENANCE COSTS

WATER QUALITY OFFICE
ENVIRONMENTAL PROTECTION AGENCY

BLACK & VEATCH
CONSULTING ENGINEERS
1971

FIGURE 46



SLUDGE LAGOONS

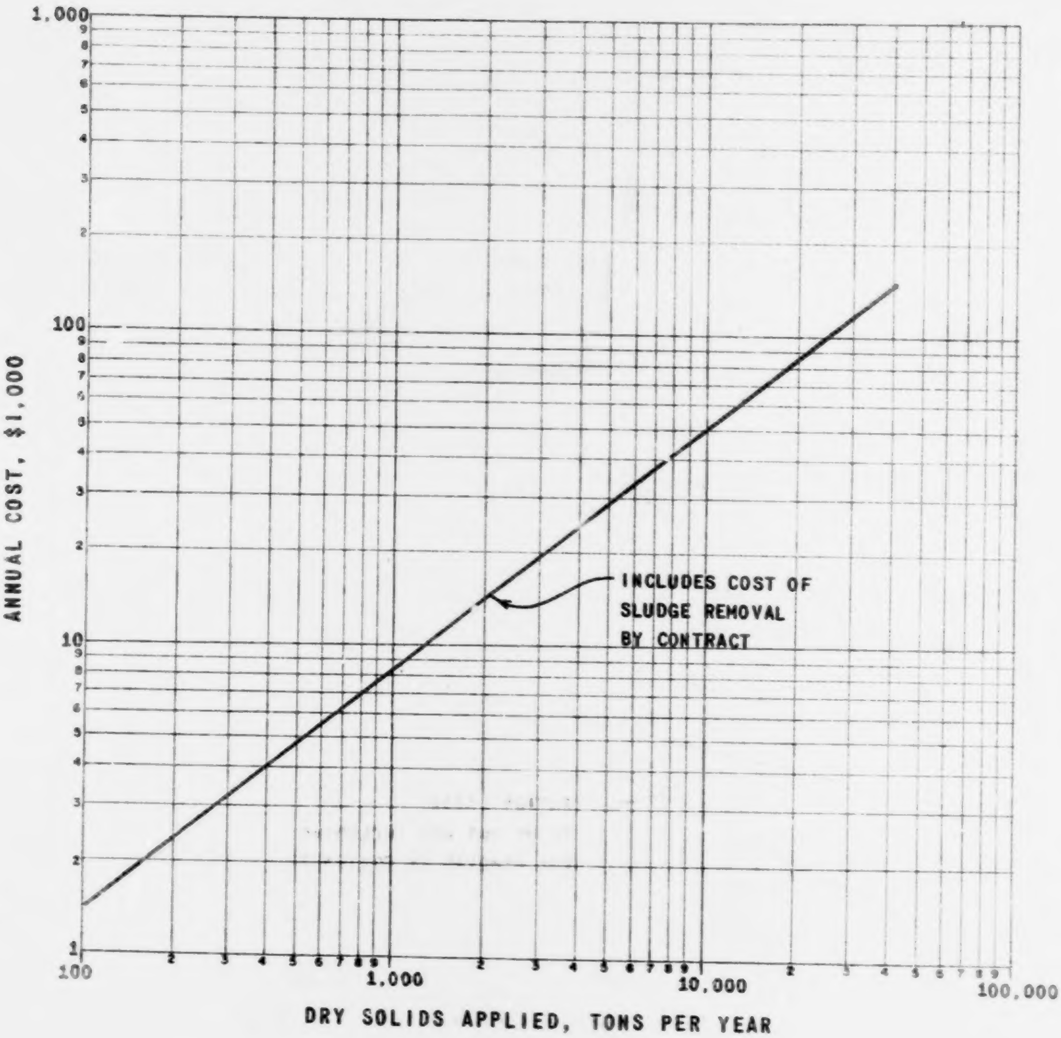
MAN-HOUR REQUIREMENTS

OPERATION AND MAINTENANCE COSTS

WATER QUALITY OFFICE
ENVIRONMENTAL PROTECTION AGENCY

BLACK & VEATCH
CONSULTING ENGINEERS
1971

FIGURE 47



INCLUDES COST OF SLUDGE REMOVAL BY CONTRACT

SLUDGE LAGOONS

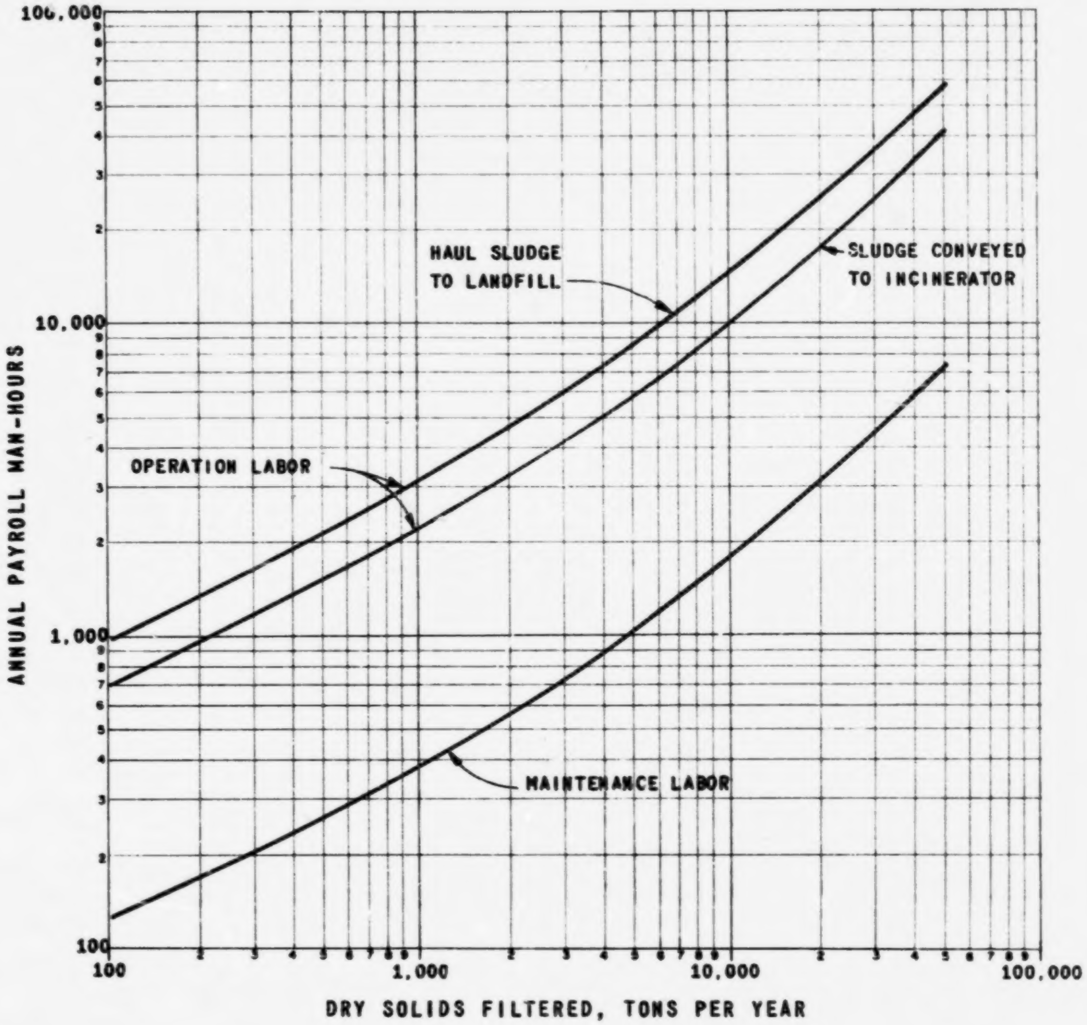
MATERIAL AND SUPPLY COSTS

OPERATION AND MAINTENANCE COSTS

WATER QUALITY OFFICE
ENVIRONMENTAL PROTECTION AGENCY

BLACK & VEATCH
CONSULTING ENGINEERS
1971

FIGURE 48



VACUUM FILTRATION

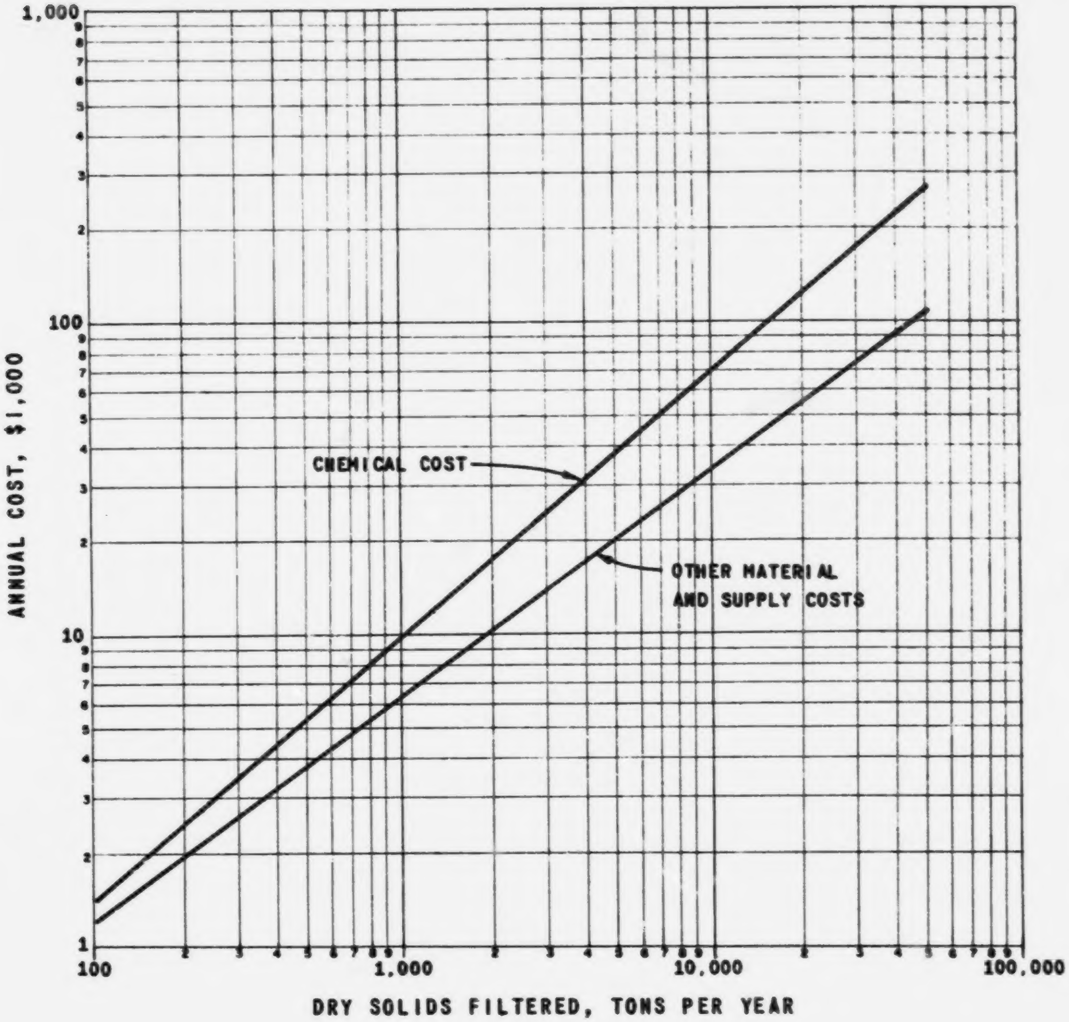
MAN-HOUR REQUIREMENTS

OPERATION AND MAINTENANCE COSTS

WATER QUALITY OFFICE
ENVIRONMENTAL PROTECTION AGENCY

BLACK & VEATCH
CONSULTING ENGINEERS
1971

FIGURE 49



VACUUM FILTRATION

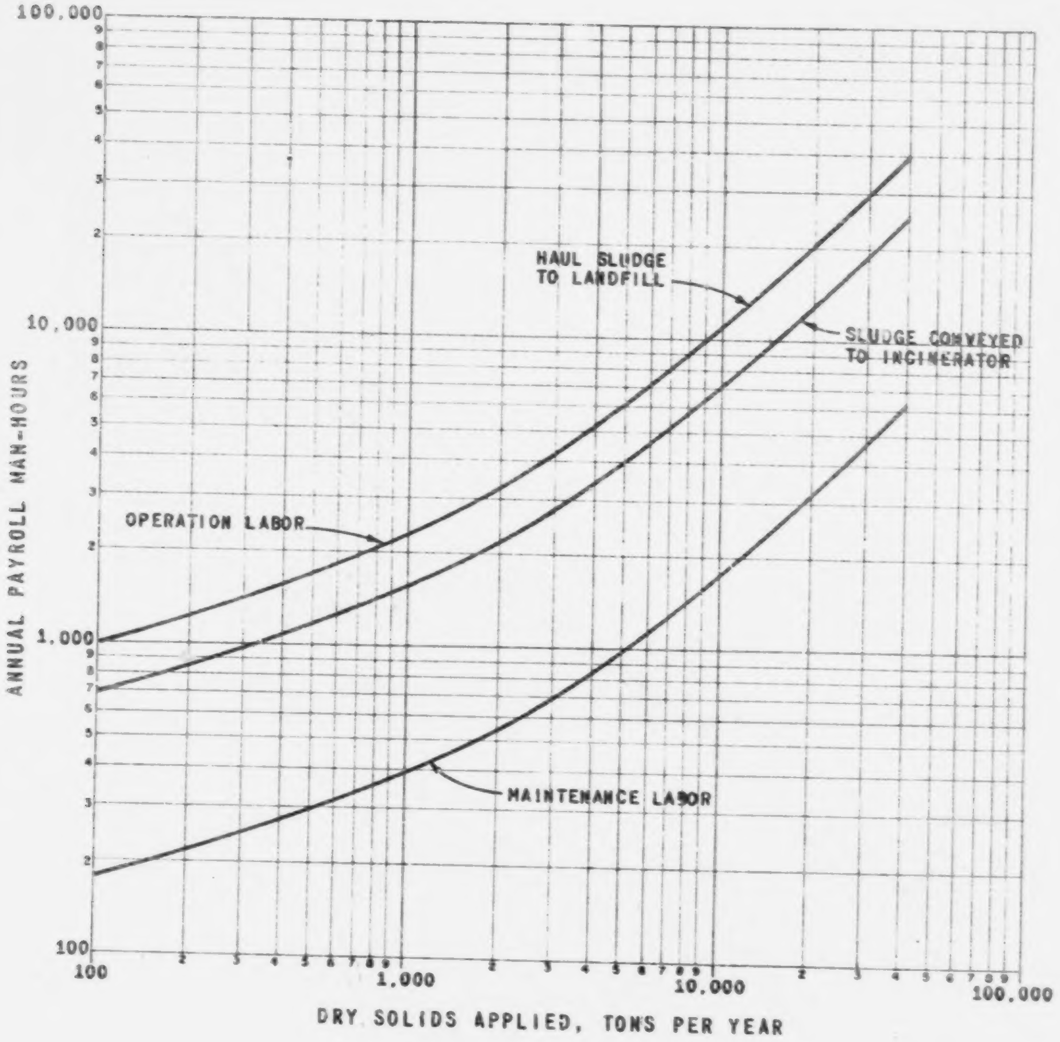
MATERIAL AND SUPPLY COSTS

OPERATION AND MAINTENANCE COSTS

WATER QUALITY OFFICE
ENVIRONMENTAL PROTECTION AGENCY

BLACK & VEATCH
CONSULTING ENGINEERS
1971

FIGURE 50



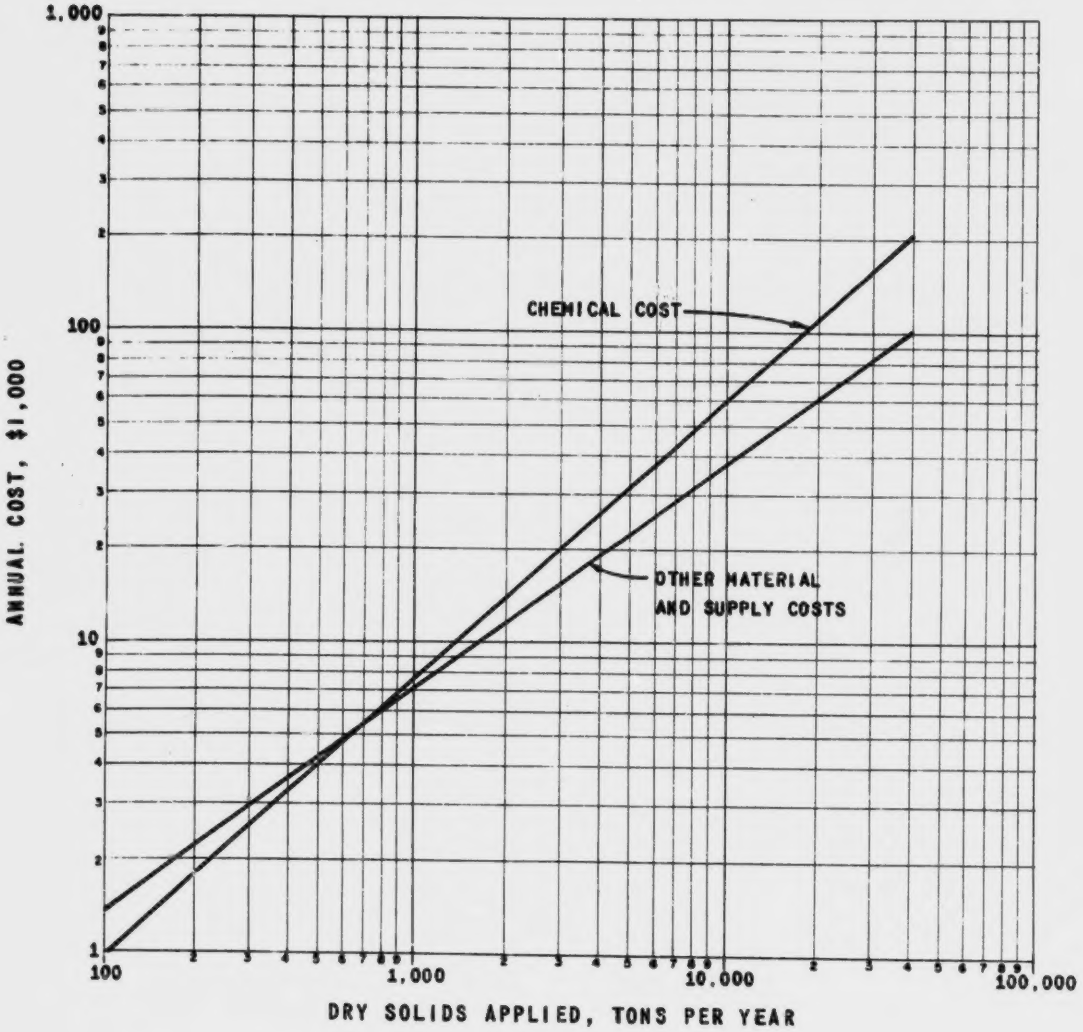
CENTRIFUGATION
MAN-HOUR REQUIREMENTS

OPERATION AND MAINTENANCE COSTS

WATER QUALITY OFFICE
ENVIRONMENTAL PROTECTION AGENCY

BLACK & VEATCH
CONSULTING ENGINEERS
1971

FIGURE 51



CENTRIFUGATION

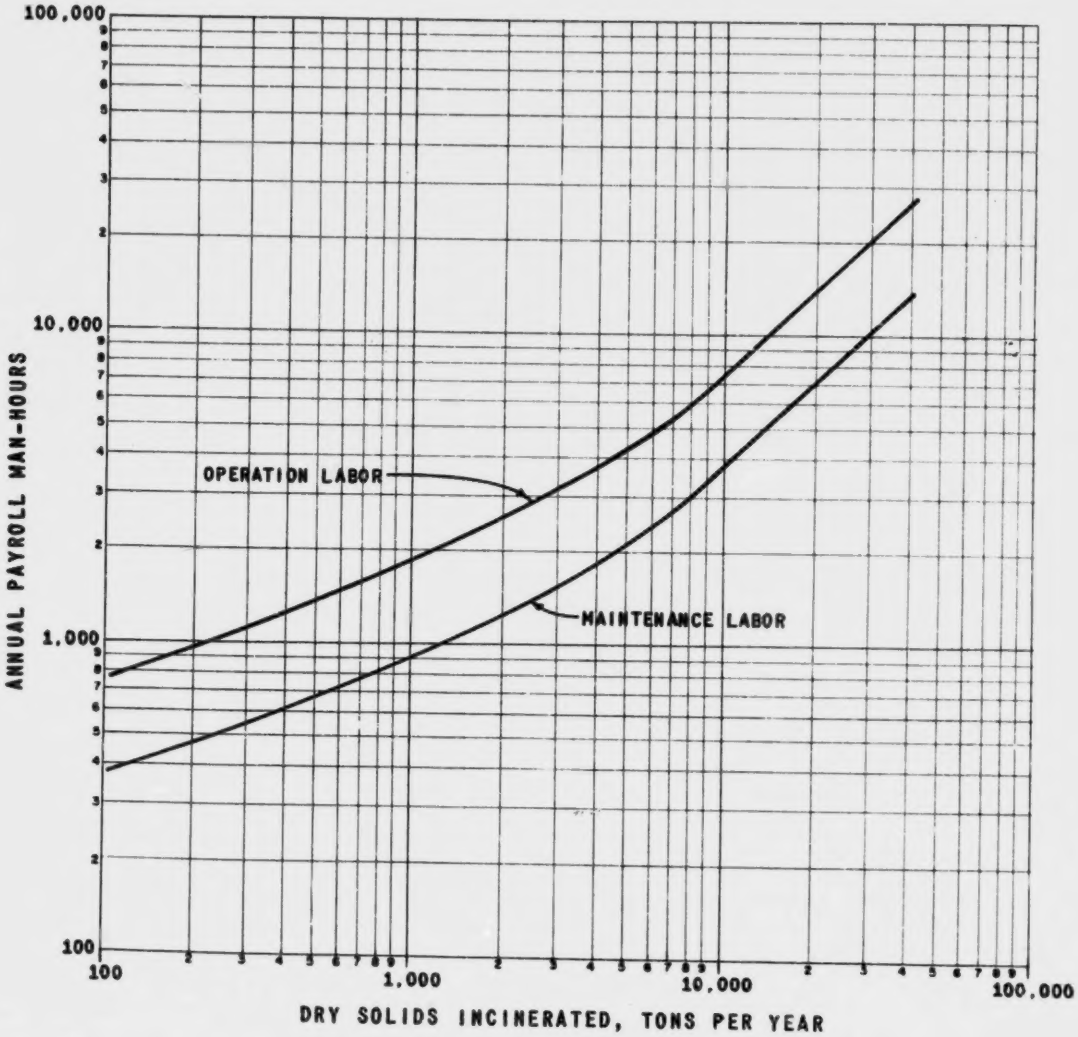
MATERIAL AND SUPPLY COSTS

OPERATION AND MAINTENANCE COSTS

WATER QUALITY OFFICE
ENVIRONMENTAL PROTECTION AGENCY

BLACK & VEATCH
CONSULTING ENGINEERS
1971

FIGURE 52



INCINERATION

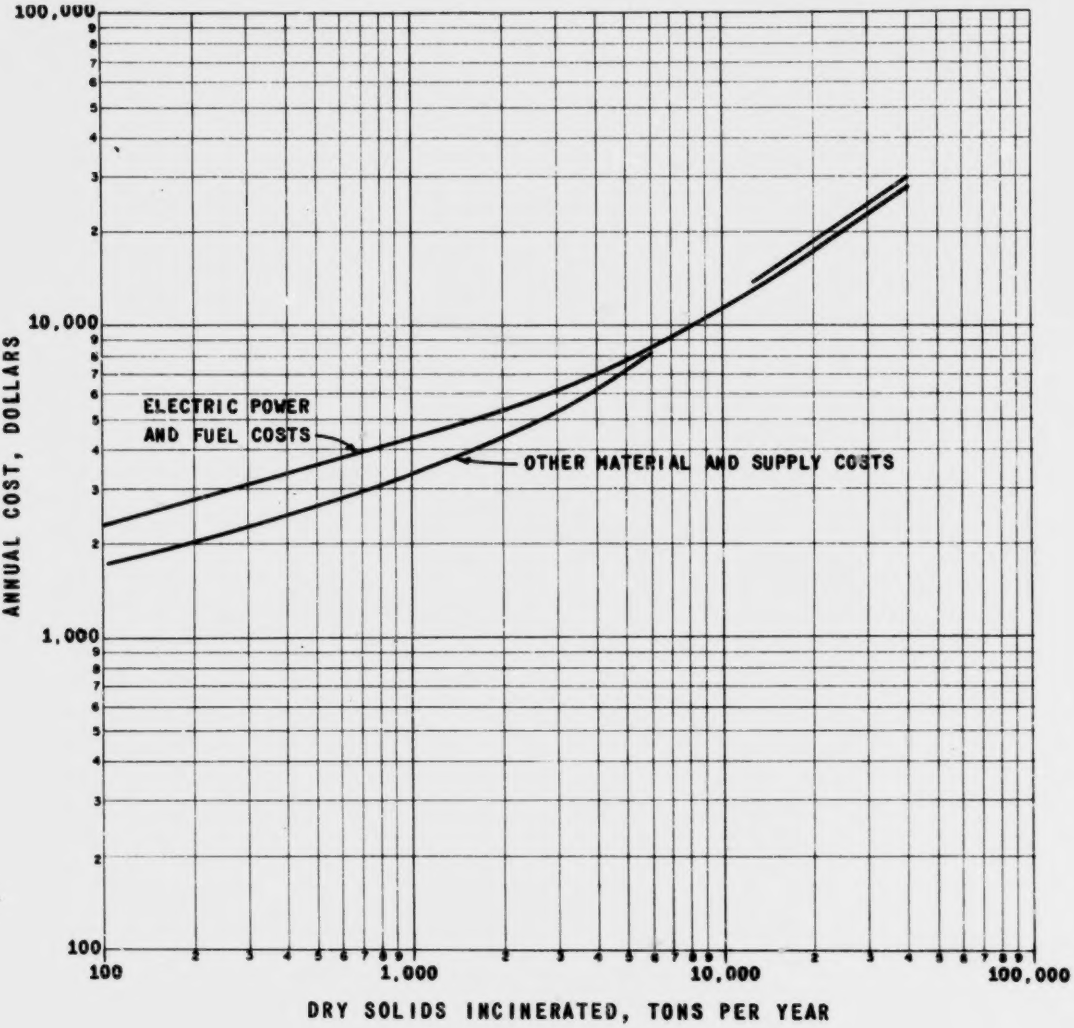
MAN-HOUR REQUIREMENTS

OPERATION AND MAINTENANCE COSTS

WATER QUALITY OFFICE
ENVIRONMENTAL PROTECTION AGENCY

BLACK & VEATCH
CONSULTING ENGINEERS
1971

FIGURE 53



INCINERATION

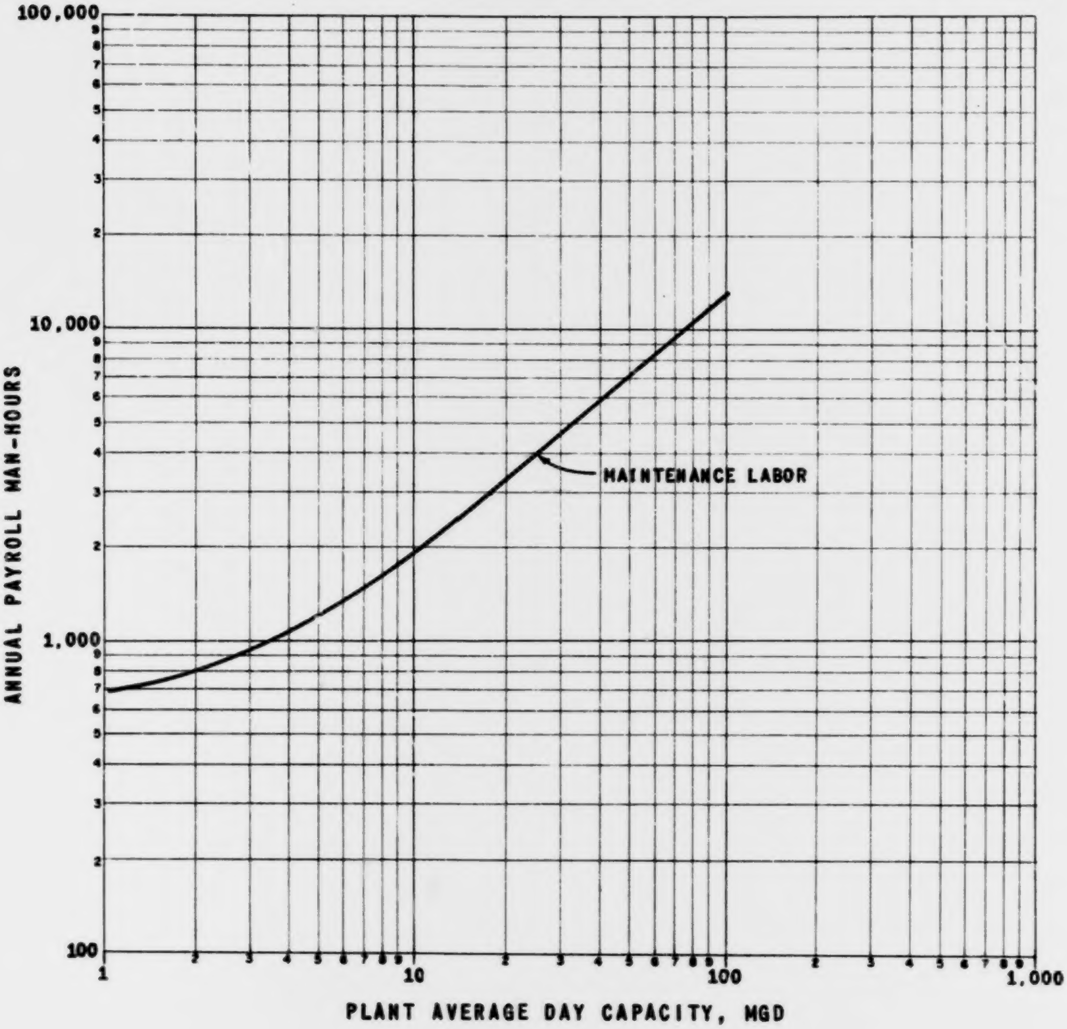
MATERIAL AND SUPPLY COSTS

OPERATION AND MAINTENANCE COSTS

WATER QUALITY OFFICE
ENVIRONMENTAL PROTECTION AGENCY

BLACK & VEATCH
CONSULTING ENGINEERS
1971

FIGURE 54



YARDWORK

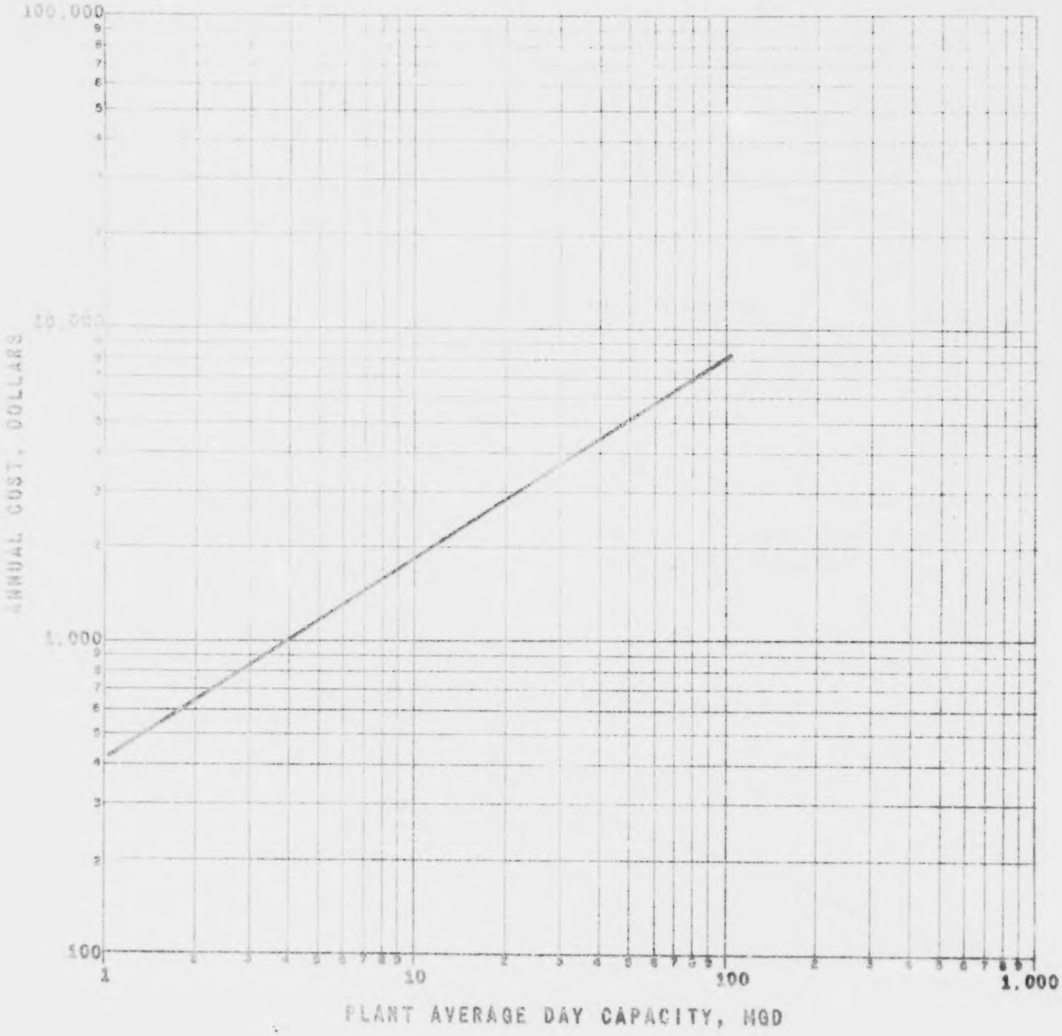
MAN-HOUR REQUIREMENTS

OPERATION AND MAINTENANCE COSTS

WATER QUALITY OFFICE
ENVIRONMENTAL PROTECTION AGENCY

BLACK & VEATCH
CONSULTING ENGINEERS
1971

FIGURE 55



YARDWORK

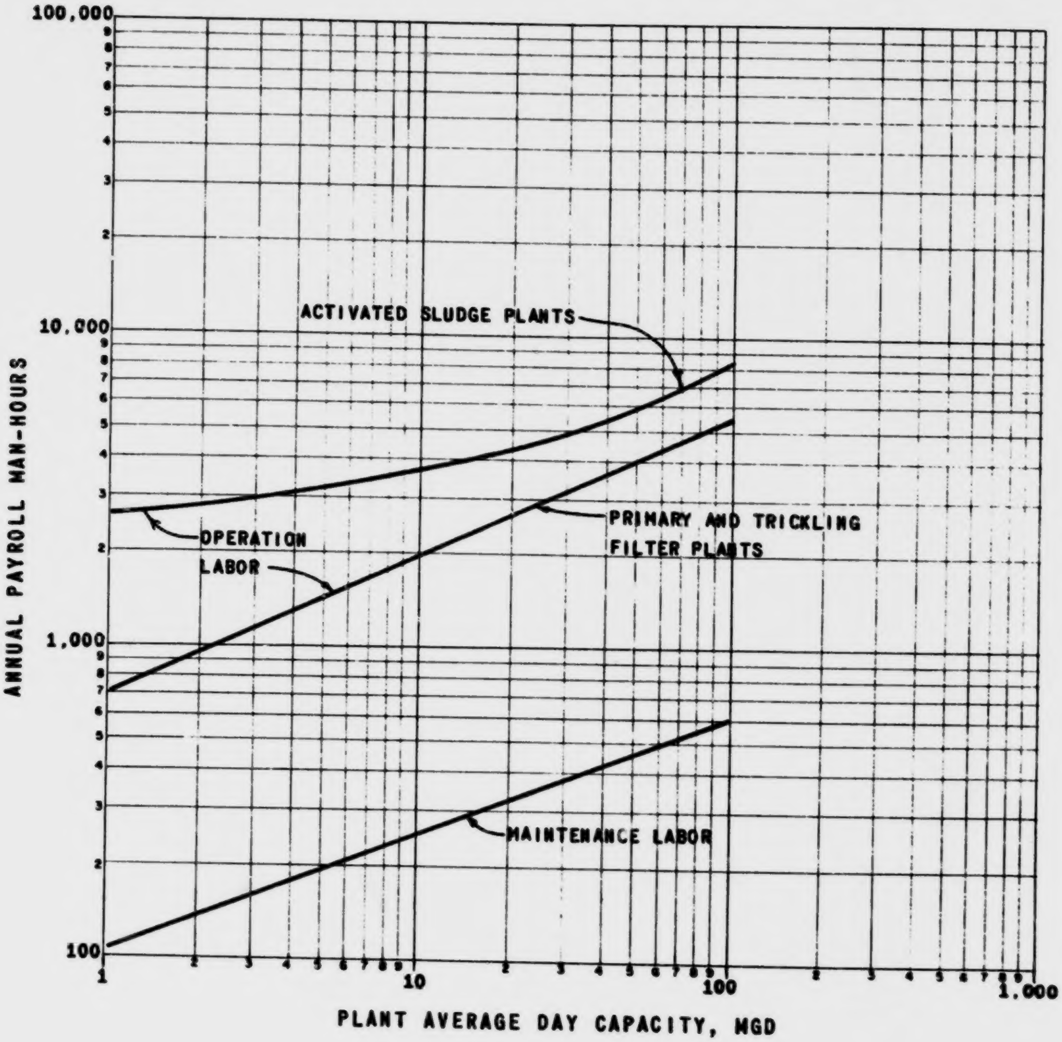
MATERIAL AND SUPPLY COSTS

OPERATION AND MAINTENANCE COSTS

WATER QUALITY OFFICE
ENVIRONMENTAL PROTECTION AGENCY

BLACK & VEATCH
CONSULTING ENGINEERS
1971

FIGURE 56



LABORATORY

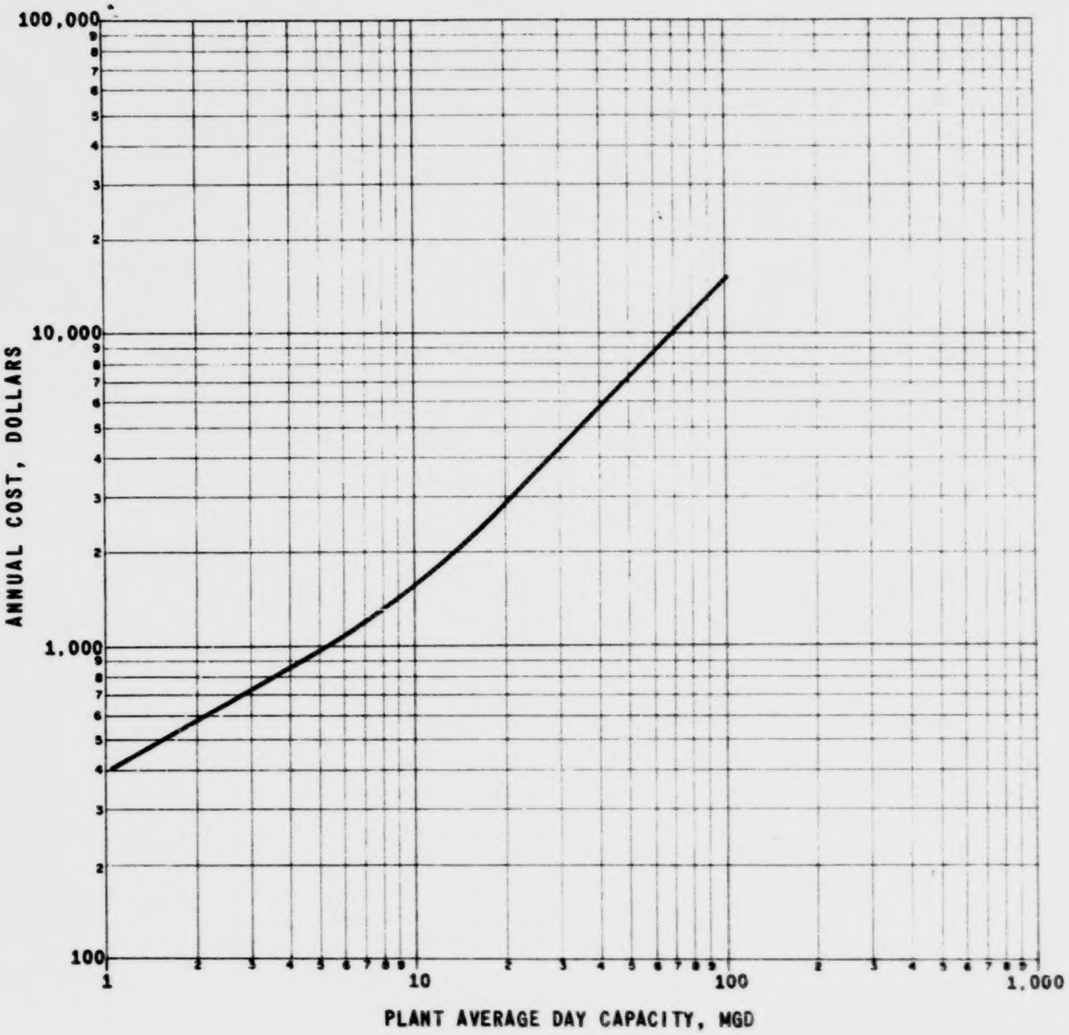
MAN-HOUR REQUIREMENTS

OPERATION AND MAINTENANCE COSTS

WATER QUALITY OFFICE
ENVIRONMENTAL PROTECTION AGENCY

BLACK & VEATCH
CONSULTING ENGINEERS
1971

FIGURE 57



LABORATORY

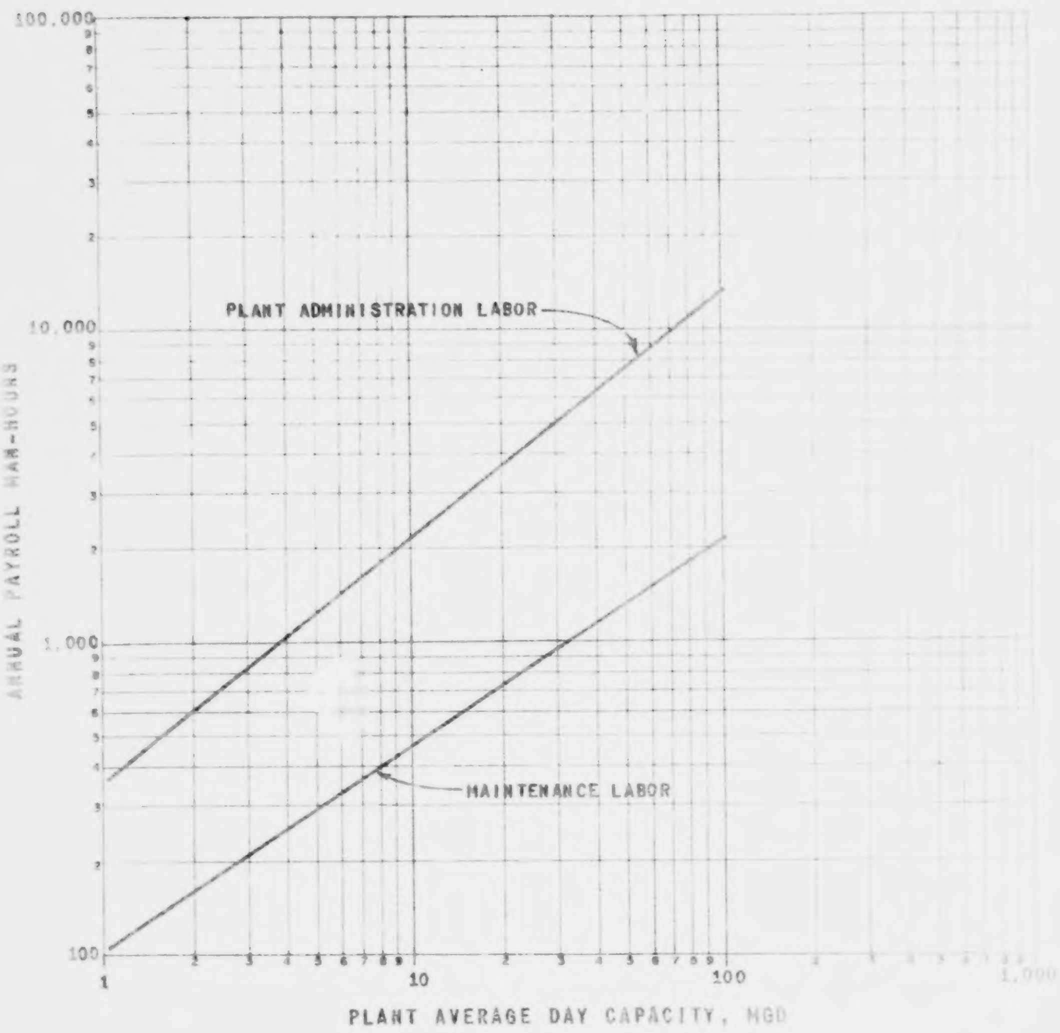
MATERIAL AND SUPPLY COSTS

OPERATION AND MAINTENANCE COSTS

WATER QUALITY OFFICE
ENVIRONMENTAL PROTECTION AGENCY

BLACK & VEATCH
CONSULTING ENGINEERS
1971

FIGURE 58



ADMINISTRATION AND GENERAL

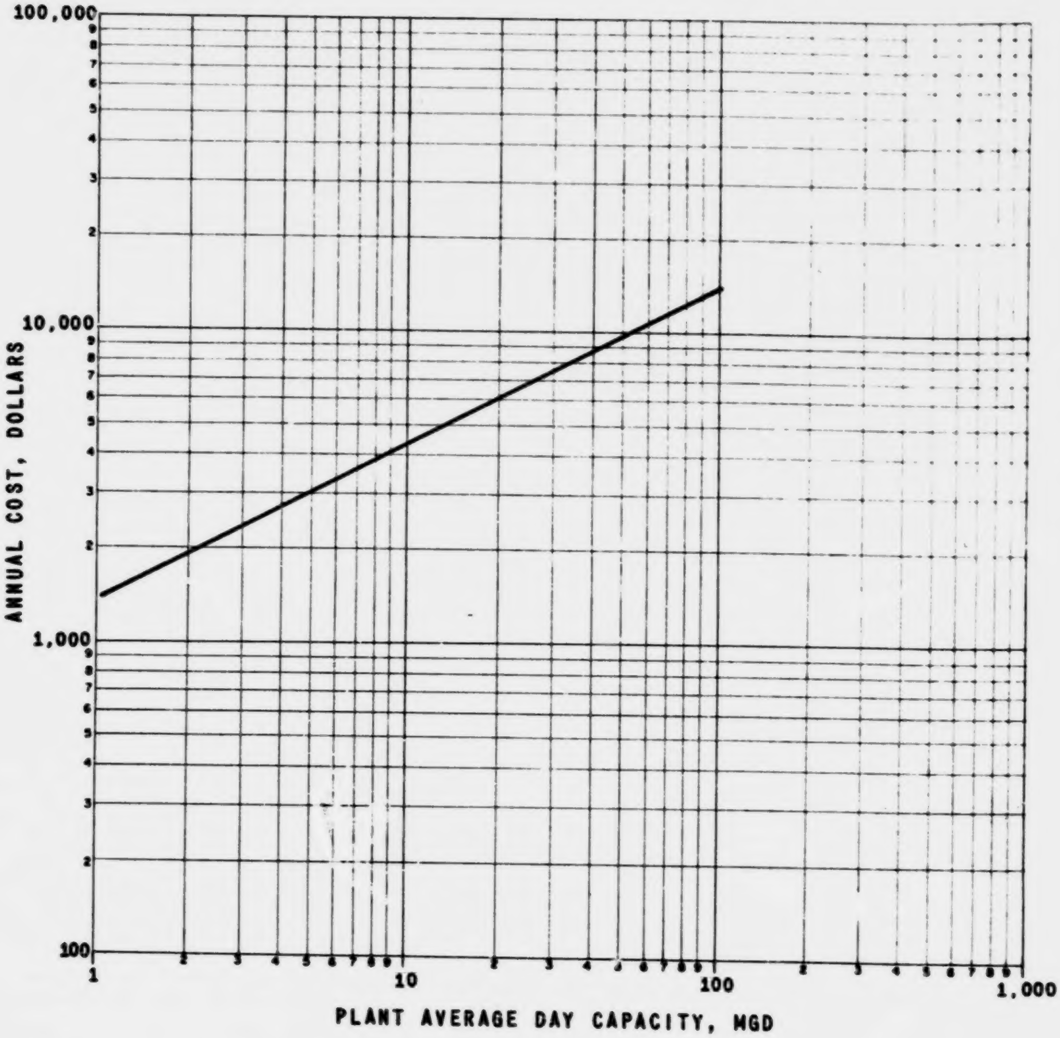
MAN-HOUR REQUIREMENTS

OPERATION AND MAINTENANCE COSTS

WATER QUALITY OFFICE
ENVIRONMENTAL PROTECTION AGENCY

BLACK & VEATCH
CONSULTING ENGINEERS
1971

FIGURE 59



ADMINISTRATION AND GENERAL

GENERAL EXPENSE

OPERATION AND MAINTENANCE COSTS

WATER QUALITY OFFICE
ENVIRONMENTAL PROTECTION AGENCY

BLACK & VEATCH
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1971

FIGURE 60

PART THREE - MANPOWER REQUIREMENTS

SECTION I

GENERAL CONSIDERATIONS

Part Three of this report presents a basis and method for estimating total manpower requirements and plant staffing for conventional wastewater treatment facilities. Also included are occupation descriptions applicable to personnel commonly required for operation and maintenance of conventional facilities.

The information presented is to assist those seeking to project future wastewater treatment plant staffing requirements as a basis for planning of manpower training programs. The report can also be utilized as a guide to staffing requirements of individual conventional treatment plants, providing recognition is given to the "average" nature of the estimating data presented, and judgment is applied regarding specific local circumstances.

The principal bases for preparation of the information presented are field investigations of 23 operating wastewater treatment plants of various types and sizes throughout the country, and the experience and judgment of the investigators.

Background information regarding field investigations and the use of estimating data developed is presented in Part Two of the report, Operation and Maintenance Costs, Section I, on Pages 59-63. Reference is subsequently made to additional sections of Part Two.

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SECTION II

OCCUPATION DESCRIPTIONS

For wastewater treatment plant staffing requirement estimating procedures to be meaningful to a broad group of engineers, administrators, and others, it is necessary to have relatively standard definitions of staff positions. Occupation descriptions for 21 types of personnel commonly employed to operate and maintain conventional wastewater treatment plant facilities have been prepared.

A significant part of the background data used in preparing occupation descriptions was obtained in conjunction with field investigations of treatment plants previously referred to. During the course of field investigations, plant operations were closely observed and discussed with supervisory personnel. Written job descriptions, where available, were studied and compared with actual tasks being performed. A three page occupational analysis form, recognizing job analysis specifications shown in the Dictionary of Occupational Titles, published by United States Department of Labor, was completed for each separate type of job. These analyses included a detailed job description; a code describing the relationship of each job to data, people, and things; a description of educational development, interests, and temperaments either required or desirable for each job; and a description of physical demands and working conditions.

On the basis of evaluation of field investigation data, occupation descriptions were developed conforming to categories and standards published in the Dictionary of Occupational Titles. Field information identified 119 separate job titles and categories. Analysis and comparison of actual duties permitted reduction of the list to 21 occupation descriptions. These descriptions include all major job duties commonly involved in the operation and maintenance of conventional wastewater treatment plants ranging in size from 1 to 100 million gallons per day, although there may well be exceptions and additions to the basic list in specific plants due to special circumstances. The occupation descriptions conform to the format and terminology of the Dictionary of Occupational Titles. They have been reviewed with analysts of the Occupational Analysis Field Center of the Department of Labor in St. Louis, Missouri as well as by other agencies of the Federal Government.

Detailed occupation descriptions for the following 21 types of personnel commonly employed for operation and maintenance of the conventional wastewater treatment plants are shown on Pages 145 through 196 of this report.

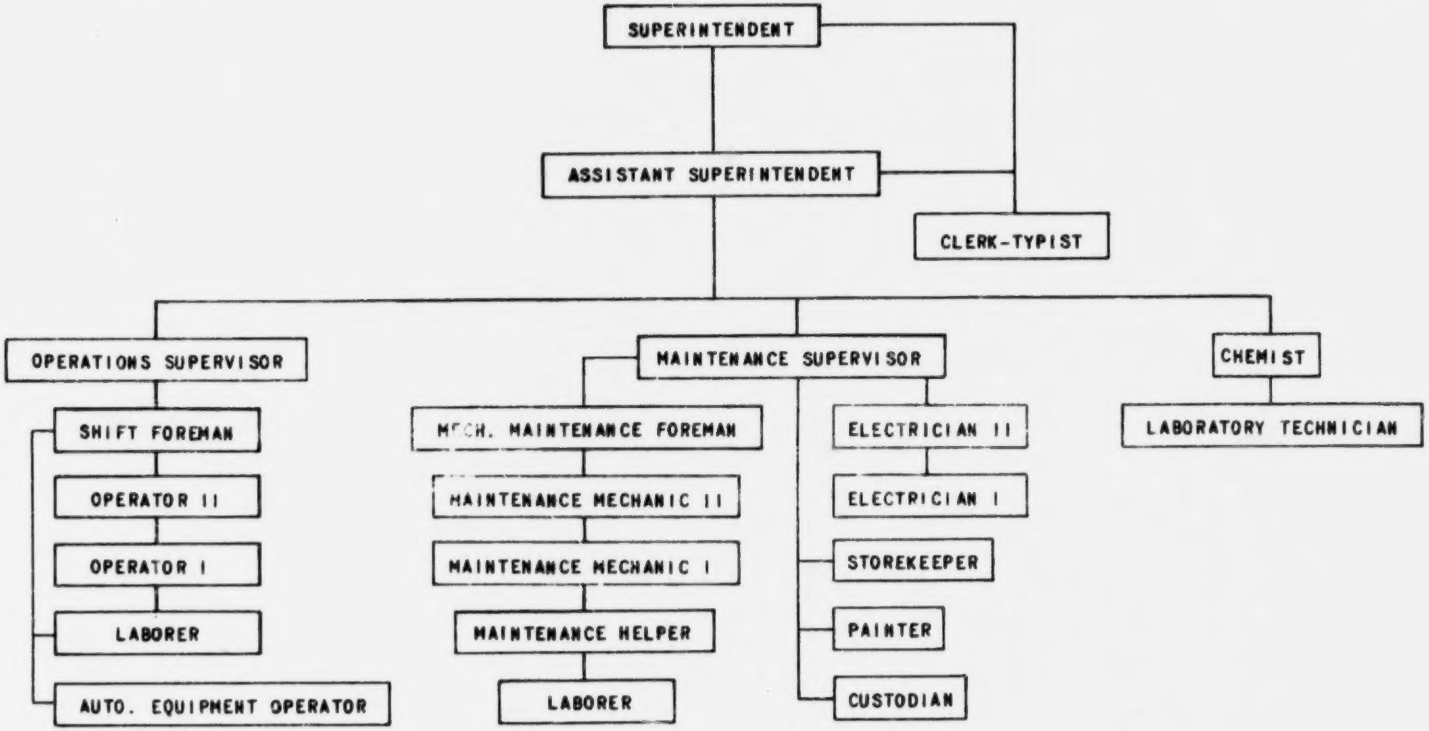
Preceding page blank

Occupation Description	Page
1. Superintendent	145
2. Assistant Superintendent	149
3. Clerk-Typist	151
4. Operations Supervisor	153
5. Shift Foreman	155
6. Operator II	159
7. Operator I	163
8. Automotive Equipment Operator	165
9. Maintenance Supervisor	167
10. Mechanical Maintenance Foreman	169
11. Maintenance Mechanic II	171
12. Maintenance Mechanic I	173
13. Electrician II	175
14. Electrician I	179
15. Maintenance Helper	181
16. Laborer	183
17. Painter	185
18. Storekeeper	187
19. Custodian	189
20. Chemist	191
21. Laboratory Technician	195

Figure 61 is an organization chart for a hypothetical wastewater treatment plant utilizing all 21 occupation categories. The chart is shown simply to illustrate the relative positions of personnel of differing responsibilities described in the 21 categories.

Separate occupation descriptions are shown where there appear to be significant differences in duties to be performed, or degree of responsibility assigned. However, separate descriptions are not shown for positions to be filled at plants of varying sizes or complexity. The descriptions are believed to be sufficiently broad in scope to permit application to varying requirements on a judgment basis. It must be recognized that in many instances, particularly at smaller plants, certain types of personnel must be sufficiently versatile to fullfill multiple functions.

Separate descriptions are not included for jobs whose functions are a specialized portion of another job description. For example, separate descriptions are shown for Operator II and Operator I because an Operator II performs more complicated duties and assumes greater responsibility than does an Operator I. Specialized titles, such as Pump Station Operator II, are not described separately, because their duties are included in the job description for Operator II.


SUPERINTENDENT
ASSISTANT SUPERINTENDENT
CLERK-TYPIST
OPERATIONS SUPERVISOR
SHIFT FOREMAN
OPERATOR II
OPERATOR I
LABORER
AUTO. EQUIPMENT OPERATOR
MAINTENANCE SUPERVISOR
MECH. MAINTENANCE FOREMAN
MAINTENANCE MECHANIC II
MAINTENANCE MECHANIC I
MAINTENANCE HELPER
LABORER
ELECTRICIAN II
ELECTRICIAN I
STOREKEEPER
PAINTER
CUSTODIAN
CHEMIST
LABORATORY TECHNICIAN

ORGANIZATION CHART
CONVENTIONAL WASTEWATER TREATMENT PLANT

WATER QUALITY OFFICE
ENVIRONMENTAL PROTECTION AGENCY

BLACK & VEATCH
CONSULTING ENGINEERS
1971

FIGURE 61

SECTION III

TOTAL MANPOWER REQUIREMENTS AND PLANT STAFFING

The total manpower requirement for a particular wastewater treatment plant covered herein is for all on-site personnel required for operation and maintenance of the facilities.

A means of estimating total annual payroll man-hour requirements for individual treatment plant components, and for total treatment facilities, is developed in Part Two of this report. Graphical relationships of total annual operation man-hours, and total annual maintenance man-hours, to sizing parameters of each of the following plant components are shown in Part Two:

1. Wastewater Pumping
2. Preliminary Treatment
3. Sedimentation
4. Trickling Filters
5. Aeration - Diffused Air System
6. Aeration - Mechanical Aerators
7. Chlorination
8. Primary Sludge Pumping
9. Sludge Holding Tanks
10. Sludge Digestion
11. Sludge Drying Beds
12. Sludge Lagoons
13. Vacuum Filtration
14. Centrifugation
15. Incineration
16. Yard Work
17. Laboratory
18. Administration and General

The annual payroll man-hours for operation and maintenance, respectively, are indicative of the total requirement for personnel to adequately operate and maintain the facility. Man-hour requirements are based on a normal payroll year consisting of 52 weeks at 40 hours per week, or a total of 2,080 hours per year. Effective working time is estimated to be 90 per cent of the payroll man-hours, with the remaining 10 per cent representing paid vacations, holidays, sick time, and other paid time away from the job. While normally full-time employees are anticipated, the payroll man-hours can be made up of a suitable combination of part-time employees.

It must be recognized that the estimates of payroll man-hour requirements shown are only representative of requirements, and are a valid basis of staffing only if the man-hours can be obtained efficiently, with any balance of an employee's time available to be used effectively elsewhere. Normally, several component parts of a plant will be operated together, making possible an efficient use of an individual employee's time.

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Table 3, Part A, on Page 79, presents a form for summarizing estimated annual payroll man-hour requirements and labor costs for any particular conventional treatment plant project. The form is shown on Table 4, modified to show only a summary of estimated operation and maintenance payroll man-hour requirements.

In using Table 4, reference is made to figures in Part Two showing estimated man-hour requirements. It is assumed that the estimator has determined from preliminary design the required capacity of plant components and quantities of wastes to be treated and, based upon this premise, the total operation and maintenance payroll man-hour requirements may be estimated.

Table 4-A illustrates the use of operation and maintenance labor requirements for estimating total payroll man-hour requirements. The example is the same as that used in Parts One and Two of this report, that is, a hypothetical wastewater treatment plant of the activated sludge type with an average design capacity of 10 million gallons per day.

In estimating staffing requirements for a particular treatment plant, payroll man-hour requirements may be summarized as to operation labor and maintenance labor, separating administrative and general and laboratory requirements. Staffing requirements by occupation titles can be developed from the labor summary. Table 5 provides a form for such a summary and development of a staff complement. In using the table, payroll man-hour requirements for the major categories of Administration & General, Operation Labor, Maintenance Labor, and Laboratory, may be obtained from the labor requirement summary in Table 4. The total number of full-time employees required may be estimated by dividing total payroll man-hours by 2,080, the number of hours in the normal payroll year.

Upon determination of the approximate number of employees in each major category, the suggested staffing is developed on a judgment basis. The division of the number of employees in the suggested staffing between operation labor and maintenance labor may not necessarily agree with the division of payroll man-hours. The difference would result from practical considerations and the fact that operating personnel frequently perform a certain amount of maintenance tasks and may conduct laboratory sampling and testing, particularly in small plants.

Other factors requiring consideration in developing a suggested staff complement include the fact that for each position which must be filled 24 hours a day, 365 days a year, it is necessary to have almost 5 employees on the payroll. Also, during certain intermittent operations, such as vacuum filtration and incineration, an above average number of employees must be on duty.

TABLE 4

ESTIMATED ANNUAL PAYROLL MAN-HOUR REQUIREMENTS

Project ______________________; Computed By ____________ Date __________

Cost Component	Component Parameter	Estimated Annual Payroll Man-Hour Requirements			
		Reference Figure No.	Operation man-hours	Maintenance man-hours	Total man-hours
Raw Wastewater Pumping	______ mgd firm pumping capacity	26	______	______	______
Preliminary Treatment	______ mgd average plant flow	28	______	______	______
Sedimentation - Primary	______ 1000 square feet surface area	30	______	______	______
Trickling Filters	______ 1000 square feet filter surface area	32	______	______	______
Aeration - Diffused Air System	______ 1000 cfm firm blower capacity	34	______	______	______
Aeration - Mechanical Aerators	______ horsepower total installed capacity	35	______	______	______
Sedimentation - Secondary	______ 1000 square feet surface area	30	______	______	______
Recirculation or Intermediate Pumping	______ mgd firm pumping capacity	26	______	______	______
Chlorination	______ tons per year chlorine use	37	______	______	______
Primary Sludge Pumping	______ gpm firm pumping capacity	39	______	______	______
Sludge Holding Tanks	______ 1000 cubic feet sludge volume	41	______	______	______
Sludge Digestion	______ 1000 cubic feet sludge volume	43	______	______	______
Sludge Drying Beds	______ tons per year dry solids applied	45	______	______	______
Sludge Lagoons	______ tons per year dry solids applied	47	______	______	______
Vacuum Filtration - Sludge to Landfill	______ tons per year dry solids filtered	49	______	______	______
Vacuum Filtration - Sludge to Incinerator	______ tons per year dry solids filtered	49	______	______	______
Centrifugation	______ tons per year dry solids applied	51	______	______	______
Incineration	______ tons per year dry solids incinerated	53	______	______	______
Yardwork	______ mgd plant average day capacity	55	______	______	______
Laboratory	______ mgd plant average day capacity	57	______	______	______
Administration and General	______ mgd plant average day capacity	59	______	______	______
______	______	______	______	______	______
______	______	______	______	______	______
______	______	______	______	______	______
______	______	______	______	______	______
______	______	______	______	______	______
Total Estimated Annual Payroll Man-Hour Requirements			______	______	______

TABLE 4-A

ESTIMATED ANNUAL PAYROLL MAN-HOUR REQUIREMENTS

Project *Newton, Nebraska* ; Computed By *RWB* Date *Sept., 1971*

Cost Component		Component Parameter	Estimated Annual Payroll Man-Hour Requirements			
			Reference Figure No.	Operation man-hours	Maintenance man-hours	Total man-hours
Raw Wastewater Pumping	*20*	mgd firm pumping capacity	26	*800*	*660*	*1,460*
Preliminary Treatment	*7.5*	mgd average plant flow	28	*1,500*	*780*	*2,280*
Sedimentation - Primary	*17*	1000 square feet surface area	30	*1,400*	*810*	*2,210*
Trickling Filters		1000 square feet filter surface area	32			
Aeration - Diffused Air System	*14*	1000 cfm firm blower capacity	34	*3,300*	*2,050*	*5,350*
Aeration - Mechanical Aerators		horsepower total installed capacity	35			
Sedimentation - Secondary	*20*	1000 square feet surface area	30	*1,450*	*860*	*2,310*
Recirculation or Intermediate Pumping	*10*	mgd firm pumping capacity	26	*620*	*530*	*1,150*
Chlorination	*115*	tons per year chlorine use	37	*1,250*	*270*	*1,520*
Primary Sludge Pumping	*180*	gpm firm pumping capacity	39	*1,250*	*540*	*1,790*
Sludge Holding Tanks	*30*	1000 cubic feet sludge volume	41	*730*	*350*	*1,080*
Sludge Digestion		1000 cubic feet sludge volume	43			
Sludge Drying Beds		tons per year dry solids applied	45			
Sludge Lagoons		tons per year dry solids applied	47			
Vacuum Filtration - Sludge to Landfill		tons per year dry solids filtered	49			
Vacuum Filtration - Sludge to Incinerator	*3,450*	tons per year dry solids filtered	49	*4,600*	*800*	*5,400*
Centrifugation		tons per year dry solids applied	51			
Incineration	*3,450*	tons per year dry solids incinerated	53	*3,300*	*1,500*	*4,800*
Yardwork	*10*	mgd plant average day capacity	55	*—*	*1,900*	*1,900*
Laboratory	*10*	mgd plant average day capacity	57	*3,600*	*240*	*3,840*
Administration and General	*10*	mgd plant average day capacity	59	*2,100*	*460*	*2,560*
Total Estimated Annual Payroll Man-Hour Requirements				*25,900*	*11,750*	*37,650*

TABLE 5

ESTIMATED PLANT STAFFING COMPLEMENT

Project ____________________; Computed By _______; Date ________

Staff Position	Estimated Annual Payroll Requirements		Suggested Staffing
	Man-Hours[a]	Number of Employees[b]	Number of Employees
Administration & General:			
Superintendent			
Assistant Superintendent			
Clerk Typist			
Storekeeper			
Subtotal	(c)		
Operation Labor:			
Operations Supervisor			
Shift Foreman			
Operator II			
Operator I			
Automotive Equipment Operator			
Subtotal	(d)		
Maintenance Labor:			
Maintenance Supervisor			
Mechanical Maintenance Foreman			
Maintenance Mechanic II			
Maintenance Mechanic I			
Electrician II			
Electrician I			
Painter			
Maintenance Helper			
Laborer			
Custodian			
Subtotal	(e)		
Laboratory:			
Chemist			
Laboratory Technician			
Subtotal	(c)		
Total Labor Requirements			

Notes:

(a) From Table 4
(b) Man-hours divided by 2,080 hours per year
(c) Operation man-hours only
(d) All operation man-hours except Administration & General and Laboratory
(e) All maintenance man-hours

The suggested staffing could include part-time personnel if local circumstances so indicated. This would most likely be the case at smaller plants and would be dependent on availability of part-time employees.

Table 5-A illustrates the use of the estimated annual payroll requirement data in developing a suggested plant staff complement. The example is based on a 10 million gallon per day activated sludge plant as used in previous examples in this report.

TABLE 5-A

ESTIMATED PLANT STAFFING COMPLEMENT

Project *Newton, Nebraska*; Computed By *RWB*; Date *Sept., 1971*

Staff Position	Estimated Annual Payroll Requirements		Suggested Staffing
	Man-Hours(a)	Number of Employees(b)	Number of Employees
Administration & General:			
Superintendent			1
Assistant Superintendent			
Clerk Typist			
Storekeeper			
Subtotal	2100 (c)	1.0	
Operation Labor:			
Operations Supervisor			
Shift Foreman			
Operator II			4
Operator I			6
Automotive Equipment Operator			
Subtotal	20,200 (d)	9.7	
Maintenance Labor:			
Maintenance Supervisor			
Mechanical Maintenance Foreman			
Maintenance Mechanic II			1
Maintenance Mechanic I			1
Electrician II			.5
Electrician I			
Painter			
Maintenance Helper			1
Laborer			2
Custodian			
Subtotal	11,750 (e)	5.7	
Laboratory:			
Chemist			
Laboratory Technician			1.5
Subtotal	3,600 (c)	1.7	
Total Labor Requirements	37,650	18.1	18

Notes:

(a) From Table 4
(b) Man-hours divided by 2,080 hours per year
(c) Operation man-hours only
(d) All operation man-hours except Administration & General and Laboratory
(e) All maintenance man-hours

SECTION IV

EXAMPLES OF WASTEWATER TREATMENT PLANT STAFFING

This section of the report presents examples of wastewater treatment plant staff complements developed in accord with the procedures previously set forth. Examples shown represent 9 differing types of conventional treatment. Each example shows estimated staff complements for 10 plant sizes, ranging from 1 to 100 mgd average day capacity.

The 9 examples illustrate typical estimated staff complements for each of 3 basic types of conventional wastewater treatment plants: primary treatment; primary plus trickling filter secondary treatment; and primary plus activated sludge secondary treatment. For each of the 3 basic types of plants, 3 examples are included, according to the method of sludge treatment employed: digestion followed by sludge drying beds or lagoons; digestion followed by sludge dewatering with land disposal of sludge cake; and sludge dewatering with incineration of sludge cake. Table 6 shows a summary of the 9 examples by type of treatment and identifies the subsequent tables on which estimated staff complements by occupation description are shown.

Each of the estimated staff complements for plants represented in Tables 7 through 15, Pages 136 through 144, was developed using methods and data set forth in this report. The typical plant components in each example are shown in the notes for respective tables. The magnitude of the parameter used in estimating payroll man-hours for each plant component was estimated on the basis of average design criteria. It must be recognized that any specific plant may not have all components sized in accord with average criteria and the examples are not specifically applicable to any particular situation.

The staff complements shown in the examples are established as general guidelines for typical average plants. They are not in any way intended to be considered as organizations which may or should be rigidly adhered to. Rather, the complements shown represent estimates of workable staffing for various types and sizes of typical conventional wastewater treatment plants, and should be considered sufficiently flexible for adaptation to particular situations at specific plants. Complements shown are based on the assumption that staff members are employed on a full-time basis, except where requirements indicate that a half-time employee in a particular occupation description would be sufficient. It is also assumed that personnel are flexible in their capabilities and willingness to perform a variety of tasks. This is particularly essential at the smaller plants.

In the examples shown, allowances for trainees are minimal. If the local labor supply cannot provide adequately qualified personnel, it may be necessary to include a substantial allowance for trainee

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TABLE 6

SUMMARY OF STAFF COMPLEMENT EXAMPLES

		Liquid Treatment			Sludge Handling Facilities		
Example No.	Table	Primary	Trickling Filters	Activated Sludge	Digestion and Beds or Lagoons	Digestion and Sludge Dewatering	Dewatering and Incineration
1	7	x			x		
2	8	x				x	
3	9	x					x
4	10	x	x		x		
5	11	x	x			x	
6	12	x	x				x
7	13	x		x	x		
8	14	x		x		x	
9	15	x		x			x

Note:

Example tables are shown on Pages 136 through 144.

personnel, in which case the staff would need to be increased accordingly. Conversely, if unusually well qualified employees are available, the total estimated staff might be reduced.

It should also be recognized that complexity of plant processes, equipment, and treatment problems can affect personnel requirements. Each plant will have unique circumstances requiring knowledge of the situation and sound judgment to develop the optimum staff.

The 9 examples presented in Tables 7 through 15 represent a practical guideline for estimating overall treatment plant staff requirements on a national average basis, and may be considered sufficiently representative for that purpose. The example staff complements should not be considered as fixed criteria for judging the adequacy of staff complements determined in special studies for specific local situations.

TABLE 7

STAFF COMPLEMENTS FOR WASTEWATER TREATMENT PLANTS
Example No. 1(a)

Occupation Title	Plant Average Day Capacity, mgd									
	1	3	5	10	20	35	50	65	80	100
	Estimated Number of Personnel									
Superintendent			.5	1	1	1	1	1	1	1
Assistant Superintendent						1	1	1	1	1
Clerk Typist					1	1	1.5	2	2	2
Operations Supervisor										1
Shift Foreman								1	1	1
Operator II	1	1	1	1	2	3	6	6	7	8
Operator I	3	4	5	4	4	5	6	6	8	8
Auto. Equipment Operator						1	1	1	2	2
Maintenance Supervisor										1
Mech. Maintenance Foreman								1	1	1
Maintenance Mechanic II				.5	1	1	1	2	2	2
Maintenance Mechanic I					1	1	1	1	2	2
Electrician II					.5	1	1	1	1	1
Electrician I							.5	.5	1	1
Maintenance Helper				1	1	1	2	2	3	4
Laborer		.5	1	1	2	4	4	5	5	7
Painter										.5
Storekeeper								1	1	1
Custodian							1	1	1	1
Chemist									.5	.5
Laboratory Technician				1	1	2	2	2	2	2
Total Staff Complement	4	5.5	7.5	9.5	14.5	22	29	34.5	41.5	48

Notes:

(a) Plant components included in this example are:

Liquid Treatment	Sludge Treatment
Raw wastewater pumping	Primary sludge pumping
Preliminary treatment	Sludge digestion
Primary sedimentation	Sludge drying beds(b) (1, 3 and 5 mgd plants)
Chlorination	Sludge lagoons(c) (10 mgd and larger plants)

Other Plant Components

- Yardwork
- Laboratory
- Administration and general

(b) Sludge removed from plant site by plant personnel.

(c) Sludge removed from plant site under contract.

TABLE 8

STAFF COMPLEMENTS FOR WASTEWATER TREATMENT PLANTS
Example No. 2(a)

Occupation Title	Plant Average Day Capacity, mgd									
	1	3	5	10	20	35	50	65	80	100
	Estimated Number of Personnel									
Superintendent		.5	.5	1	1	1	1	1	1	1
Assistant Superintendent						1	1	1	1	1
Clerk Typist					1	1	1.5	2	2	2
Operations Supervisor									1	1
Shift Foreman							1	1	1	2
Operator II	1	1	2	2	3	5	6	7	9	10
Operator I	3	3	3	3	5	6	8	8	10	11
Auto. Equipment Operator		1	1	1	1	2	2	4	4	4
Maintenance Supervisor										1
Mech. Maintenance Foreman							1	1	1	1
Maintenance Mechanic II				.5	1	1	2	2	2	2
Maintenance Mechanic I					1	1	1	1	2	2
Electrician II					.5	1	1	1	1	2
Electrician I							.5	.5	1	1
Maintenance Helper				1	1	1	2	3	3	4
Laborer		.5	1	2	2	4	4	5	5	7
Painter									.5	.5
Storekeeper								1	1	1
Custodian							1	1	1	1
Chemist									.5	.5
Laboratory Technician				1	1	2	2	2	2	2
Total Staff Complement	4	6	7.5	11.5	17.5	26	35	41.5	49	57

Notes:

(a) Plant components included in this example are:

Liquid Treatment	Sludge Treatment
Raw wastewater pumping	Primary sludge pumping
Preliminary treatment	Sludge digestion
Primary sedimentation	Sludge holding tanks
Chlorination	Vacuum filtration(b)

Other Plant Components
- Yardwork
- Laboratory
- Administration and general

(b) Filter cake hauled from plant site by plant personnel.

TABLE 9

STAFF COMPLEMENTS FOR WASTEWATER TREATMENT PLANTS
Example No. 3(a)

Occupation Title	Plant Average Day Capacity, mgd									
	1	3	5	10	20	35	50	65	80	100
	Estimated Number of Personnel									
Superintendent		.5	.5	1	1	1	1	1	1	1
Assistant Superintendent						1	1	1	1	1
Clerk Typist					1	1	1.5	2	2	2
Operations Supervisor									1	1
Shift Foreman							1	1	1	2
Operator II	1	1	2	2	3	5	6	7	9	10
Operator I	3	4	4	4	6	7	8	11	12	13
Auto. Equipment Operator						1	1	1	2	2
Maintenance Supervisor										1
Mech. Maintenance Foreman							1	1	1	1
Maintenance Mechanic II				1	1	1	2	2	2	2
Maintenance Mechanic I					1	1	1	1	2	2
Electrician II					.5	1	1	1	1	2
Electrician I							.5	1	1	1
Maintenance Helper				1	1	1	2	2	3	4
Laborer		.5	1	1	2	4	3	5	5	7
Painter									.5	.5
Storekeeper								1	1	1
Custodian							1	1	1	1
Chemist									.5	.5
Laboratory Technician			.5	1	1	2	2	2	2	2
Total Staff Complement	4	6	8	11	17.5	26	33	41	49	57

Notes:

(a) Plant components included in this example are:

Liquid Treatment
Raw wastewater pumping
Preliminary treatment
Primary sedimentation
Chlorination

Sludge Treatment
Primary sludge pumping
Sludge holding tanks
Vacuum filtration
Incineration(b)

Other Plant Components
Yardwork
Laboratory
Administration and general

(b) Ashes removed from plant site under contract.

TABLE 10

STAFF COMPLEMENTS FOR WASTEWATER TREATMENT PLANTS

Example No. 4(a)

Occupation Title	Plant Average Day Capacity, mgd									
	1	3	5	10	20	35	50	65	80	100
	Estimated Number of Personnel									
Superintendent		.5	.5	1	1	1	1	1	1	1
Assistant Superintendent						1	1	1	1	1
Clerk Typist					1	1	2	2	2	3
Operations Supervisor									1	1
Shift Foreman							1	1	2	3
Operator II	1	2	2	3	5	5	7	10	10	10
Operator I	4	4	5	4	5	7	8	10	11	14
Auto. Equipment Operator						1	1	1	2	2
Maintenance Supervisor									1	1
Mech. Maintenance Foreman						1	1	1	2	2
Maintenance Mechanic II				1	1	2	2	2	2	2
Maintenance Mechanic I					1	1	1	2	2	2
Electrician II					.5	1	1	1	1	2
Electrician I							1	1	1	1
Maintenance Helper			1	1	1	2	3	4	4	5
Laborer		1	1	1	3	4	4	5	6	8
Painter									.5	1
Storekeeper								1	1	1
Custodian							1	1	1	1
Chemist									.5	.5
Laboratory Technician			.5	1	1	2	2	2	2	2
Total Staff Complement	5	7.5	10	12	19.5	29	37	46	54	63.5

Notes:

(a) Plant components included in this example are:

Liquid Treatment	Sludge Treatment
Raw wastewater pumping	Primary sludge pumping
Preliminary treatment	Sludge digestion
Primary sedimentation	Sludge drying beds(b) (1, 3 and 5 mgd plants)
Trickling filters	Sludge lagoons(c) (10 mgd and larger plants)
Final sedimentation	
Recirculation pumping	
Chlorination	

Other Plant Components

Yardwork

Laboratory

Administration and general

(b) Sludge removed from plant site by plant personnel.

(c) Sludge removed from plant site under contract.

TABLE 11

STAFF COMPLEMENTS FOR WASTEWATER TREATMENT PLANTS

Example No. 5(a)

Occupation Title	Plant Average Day Capacity, mgd									
	1	3	5	10	20	35	50	65	80	100
	Estimated Number of Personnel									
Superintendent		.5	.5	1	1	1	1	1	1	1
Assistant Superintendent						1	1	1	1	1
Clerk Typist					1	1	2	2	2	3
Operations Supervisor								1	1	1
Shift Foreman						1	2	2	3	3
Operator II	2	2	2	3	5	6	8	10	11	14
Operator I	3	4	4	5	6	10	10	13	15	18
Auto. Equipment Operator		1	1	1	3	3	4	4	6	6
Maintenance Supervisor								1	1	1
Mech. Maintenance Foreman						1	1	1	2	2
Maintenance Mechanic II				1	1	2	2	2	2	2
Maintenance Mechanic I					1	1	2	2	2	3
Electrician II					1	1	1	1	2	2
Electrician I							1	1	1	2
Maintenance Helper			1	1	1	2	3	4	4	5
Laborer		.5	1	2	3	4	4	5	6	8
Painter								.5	1	1
Storekeeper								1	1	1
Custodian							1	1	1	1
Chemist									.5	.5
Laboratory Technician			.5	1	1	2	2	2	2	2
Total Staff Complement	5	8	10	15	24	36	45	55.5	65.5	77.5

Notes:

(a) Plant components included in this example are:

Liquid Treatment	Sludge Treatment
Raw wastewater pumping	Primary sludge pumping
Preliminary treatment	Sludge digestion
Primary sedimentation	Sludge holding tanks
Trickling filters	Vacuum filtration(b)
Final sedimentation	
Recirculation pumping	
Chlorination	

Other Plant Components

- Yardwork
- Laboratory
- Administration and general

(b) Filter cake hauled from plant site by plant personnel.

TABLE 12

STAFF COMPLEMENTS FOR WASTEWATER TREATMENT PLANTS
Example No. 6[a]

Occupation Title	Plant Average Day Capacity, mgd									
	1	3	5	10	20	35	50	65	80	100
	Estimated Number of Personnel									
Superintendent		.5	.5	1	1	1	1	1	1	1
Assistant Superintendent						1	1	1	1	1
Clerk Typist					1	1	2	2	2	3
Operations Supervisor							1	1	1	1
Shift Foreman						1	2	3	3	4
Operator II	2	3	3	3	5	7	9	11	14	17
Operator I	3	4	4	6	8	10	13	14	19	22
Auto. Equipment Operator						1	1	1	2	2
Maintenance Supervisor							1	1	1	1
Mech. Maintenance Foreman						1	1	1	2	2
Maintenance Mechanic II				1	2	2	2	2	2	2
Maintenance Mechanic I					1	2	2	2	2	3
Electrician II					1	1	1	1	2	2
Electrician I							1	1	1	2
Maintenance Helper			1	1	1	2	3	4	4	5
Laborer	.5	.5	1	2	3	4	4	5	6	8
Painter								.5	1	1
Storekeeper								1	1	1
Custodian							1	1	1	1
Chemist									.5	.5
Laboratory Technician			1	1	1	2	2	2	2	2
Total Staff Complement	5.5	8	10.5	15	24	36	48	55.5	68.5	81.5

Notes:

(a) Plant components included in this example are:

Liquid Treatment	Sludge Treatment
Raw wastewater pumping	Primary sludge pumping
Preliminary treatment	Sludge holding tanks
Primary sedimentation	Vacuum filtration
Trickling filters	Incineration[b]
Final sedimentation	
Recirculation pumping	
Chlorination	

Other Plant Components

- Yardwork
- Laboratory
- Administration and general

(b) Ashes removed from plant site under contract.

TABLE 13

STAFF COMPLEMENTS FOR WASTEWATER TREATMENT PLANTS

Example No. 7[(a)]

Occupation Title	Plant Average Day Capacity, mgd									
	1	3	5	10	20	35	50	65	80	100
	Estimated Number of Personnel									
Superintendent		.5	.5	1	1	1	1	1	1	1
Assistant Superintendent						1	1	1	1	1
Clerk Typist					1	1	2	2	3	4
Operations Supervisor							1	1	1	1
Shift Foreman						1	1	2	3	4
Operator II	1	2	3	4	5	5	8	10	10	12
Operator I	4	5	6	5	7	10	10	11	14	15
Auto. Equipment Operator						1	1	2	2	2
Maintenance Supervisor								1	1	1
Mech. Maintenance Foreman						1	1	1	2	3
Maintenance Mechanic II				1	1	2	2	2	2	3
Maintenance Mechanic I				.5	1	1	2	2	2	2
Electrician II					1	1	1	2	2	2
Electrician I						1	1	1	1	1
Maintenance Helper			1	1	2	3	4	4	5	6
Laborer	.5	1	1	2	3	4	5	6	7	8
Painter								.5	1	1
Storekeeper								1	1	1
Custodian							1	1	1	1
Chemist									.5	1
Laboratory Technician	1	1	1	1.5	2	2	3	3	3	3
Total Staff Complement	6.5	9.5	12.5	16	24	35	45	54.5	63.5	73

Notes:

(a) Plant components included in this example are:

Liquid Treatment
Raw wastewater pumping
Preliminary treatment
Primary sedimentation
Aeration
Final sedimentation
Recirculation pumping
Chlorination

Sludge Treatment
Primary sludge pumping
Sludge digestion
Sludge drying beds[(b)]
(1, 3 and 5 mgd plants)
Sludge lagoons[(c)]
(10 mgd and larger plants)

Other Plant Components
Yardwork
Laboratory
Administration and general

(b) Sludge removed from plant site by plant personnel.
(c) Sludge removed from plant site under contract.

TABLE 14

STAFF COMPLEMENTS FOR WASTEWATER TREATMENT PLANTS
Example No. 8[a]

Occupation Title	Plant Average Day Capacity, mgd									
	1	3	5	10	20	35	50	65	80	100
	Estimated Number of Personnel									
Superintendent		.5	.5	1	1	1	1	1	1	1
Assistant Superintendent						1	1	1	1	1
Clerk Typist					1	1	2	2	3	4
Operations Supervisor							1	1	1	1
Shift Foreman						1	2	2	3	5
Operator II	2	3	3	4	5	7	10	12	13	16
Operator I	3	4	5	6	9	11	12	17	18	20
Auto. Equipment Operator	1	1	1	1	3	4	4	5	6	6
Maintenance Supervisor								1	1	1
Mech. Maintenance Foreman						1	1	2	3	3
Maintenance Mechanic II				1	1	2	2	2	2	3
Maintenance Mechanic I				1	1	2	2	2	2	2
Electrician II				.5	1	1	1	2	2	2
Electrician I						1	1	1	1	2
Maintenance Helper			1	1	2	3	4	4	5	6
Laborer		.5	1	2	3	4	5	6	7	8
Painter								.5	1	1
Storekeeper								1	1	1
Custodian							1	1	1	1
Chemist									.5	1
Laboratory Technician	1	1	1	1.5	2	2	3	3	3	3
Total Staff Complement	7	10	12.5	19	29	42	53	66.5	75.5	88

Notes:

(a) Plant components included in this example are:

Liquid Treatment	Sludge Treatment
Raw wastewater pumping	Primary sludge pumping
Preliminary treatment	Sludge digestion
Primary sedimentation	Sludge holding tanks
Aeration	Vacuum filtration[b]
Final sedimentation	
Recirculation pumping	
Chlorination	

Other Plant Components
- Yardwork
- Laboratory
- Administration and general

(b) Filter cake hauled from plant site by plant personnel.

TABLE 15

STAFF COMPLEMENTS FOR WASTEWATER TREATMENT PLANTS
Example No. 9(a)

Occupation Title	Plant Average Day Capacity, mgd									
	1	3	5	10	20	35	50	65	80	100
	Estimated Number of Personnel									
Superintendent		.5	.5	1	1	1	1	1	1	1
Assistant Superintendent						1	1	1	1	1
Clerk Typist					1	1	2	2	3	4
Operations Supervisor							1	1	1	1
Shift Foreman						1	2	3	3	5
Operator II	2	3	4	4	5	8	11	12	15	17
Operator I	4	5	6	6	9	12	14	17	19	25
Auto. Equipment Operator						1	1	2	2	2
Maintenance Supervisor								1	1	1
Mech. Maintenance Foreman						1	1	2	3	3
Maintenance Mechanic II				1	2	2	2	2	2	3
Maintenance Mechanic I				1	1	2	2	2	2	2
Electrician II				.5	1	1	1	2	2	2
Electrician I						1	1	1	1	2
Maintenance Helper				1	2	3	4	4	5	6
Laborer		.5	1	2	3	4	5	6	7	8
Painter								.5	1	1
Storekeeper								1	1	1
Custodian							1	1	1	1
Chemist									.5	1
Laboratory Technician	1	1	1	1.5	2	2	3	3	3	3
Total Staff Complement	7	10	12.5	18	27	41	53	64.5	74.5	90

Notes:

(a) Plant components included in this example are:

Liquid Treatment	Sludge Treatment
Raw wastewater pumping	Primary sludge pumping
Preliminary treatment	Sludge holding tanks
Primary sedimentation	Vacuum filtration
Aeration	Incineration(b)
Final sedimentation	
Recirculation pumping	
Chlorination	

Other Plant Components

- Yardwork
- Laboratory
- Administration and general

(b) Ashes hauled from plant site under contract.

OCCUPATION DESCRIPTION

Title: SUPERINTENDENT, WASTEWATER TREATMENT PLANT

JOB DESCRIPTION

Responsible for administration, operation, and maintenance of entire plant. Exercises direct authority over all plant functions and personnel, in accordance with approved policies and procedures. Inspects plant regularly. Analyzes and evaluates operation and maintenance functions; initiates or recommends new or improved practices. Develops plans and procedures to insure efficient plant operation. Recommends plant improvements and additions. Coordinates data and prepares or reviews and approves operation reports and budget requests. Controls expenditure of budgeted funds and requests approval for major expenditures, if required. Recommends specifications for major equipment and material purchases. Organizes and directs activities of plant personnel, including training programs. Maintains effective communications and working relationships with employees, government officials, and general public.

QUALIFICATIONS PROFILE

1. Formal Education

   College degree in sanitary, civil, chemical, or mechanical engineering highly desirable. Minimum high school graduate or equivalent, plus 5 to 7 years practical experience in treatment plant operations, depending upon size and complexity of plant.

2. General Requirements
   a. Knowledge of processes and equipment involved in wastewater treatment, including basic chemical, bacteriological, and biological processes.
   b. Understanding of managerial, administrative, and accounting practices and procedures involved in successful plant operation.
   c. Knowledge of industrial wastes and their effects on treatment processes and equipment.
   d. Ability to prepare or supervise preparation of clear, concise reports and budget recommendations.
   e. Ability to plan, direct, and evaluate plant operation and maintenance functions.
   f. Ability to establish and maintain effective communication and working relationships.

Title: SUPERINTENDENT (Cont'd)

3. General Educational Development
   a. Reasoning
      (1) Apply principles of logic to define problems, collect and analyze data, and draw valid conclusions. Deal with a variety of concrete and abstract variables.
      (2) Interpret a wide variety of technical instructions, in book, manual, and mathematical or diagrammatic form.
   b. Mathematical
      Perform ordinary arithmetical, algebraic, and geometric procedures in standard, practical applications.
   c. Language
      (1) Write and edit operation reports.
      (2) Evaluate and interpret engineering and other technical data.
      (3) Interview applicants and employees.
      (4) Establish and maintain communications with employees, government officals, and the public.

4. Specific Vocational Preparation
   a. Completion of operator training course or equivalent training and experience.
   b. Five to 7 years experience in wastewater treatment plant operation, depending upon size and complexity of plant and educational background. Minimum of one year supervisory experience.

5. Aptitudes-Relative to General Working Population
   a. Intelligence) Highest third excluding
   b. Verbal) top 10 per cent
   c. Numerical)
   d. Form Perception)
   e. Spatial)
   f. Clerical Perception)
   g. Motor Coordination) Middle third
   h. Finger Dexterity)
   i. Manual Dexterity)
   j. Eye-Hand-Foot Coordination)
   k. Color Discrimination)

6. Interests
   Prefer working with people in situations involving organization and supervision of varied activities.

7. Temperament
   Prefer situations involving the direction, control, and planning of an entire activity or the activity of others.

Title: SUPERINTENDENT (Cont'd)

8. Physical Demands

   Sedentary work, except for regular plant inspection trips.

9. Working Conditions

   Largely inside. Occasional exposure to weather, fumes, odors, dust, and risk of bodily injury. Possible exposure to toxic conditions.

ENTRY SOURCES: Assistant Superintendent, Operations Supervisor, Shift Foreman, or Chief Chemist; depending on individual qualifications and size and complexity of plant.

PROGRESSION TO: Similar position in larger or more complex plant.

OCCUPATION DESCRIPTION

Title: ASSISTANT SUPERINTENDENT, WASTEWATER TREATMENT PLANT

JOB DESCRIPTION

Assists in administrative and supervisory duties, under general direction of superintendent. Serves as superintendent in his absence. Aids in analyzing and evaluating operating and maintenance procedures, and in developing new or improved practices. Participates in maintenance of operating records, compilation of data, and report preparation. Assists in employee training. Inspects plant. Assists in planning special maintenance work and minor plant alterations.

QUALIFICATIONS PROFILE

1. Formal Education
   College degree in sanitary, civil, chemical, or mechanical engineering highly desirable. Minimum high school graduate or equivalent, plus 3 to 5 years practical experience in wastewater treatment plant operations, depending upon size and complexity of plant.

2. General Requirements
   a. Knowledge of processes and equipment involved in wastewater treatment.
   b. Ability to plan, direct, and evaluate plant operation and maintenance functions.
   c. Ability to prepare reports and budget recommendations.
   d. Ability to establish and maintain effective communication and working relationships.

3. General Educational Development
   a. Reasoning
      (1) Apply principles of logic to define problems, collect and analyze data, and draw valid conclusions.
      (2) Interpret a variety of technical instructions in book, manual, mathematical or diagrammatic form.
   b. Mathematical
      Perform ordinary arithmetical, algebraic, and geometric procedures in standard, practical applications.

   c. Language
      (1) Write or assist in preparation of operation reports.
      (2) Evaluate and interpret engineering and other technical data.

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Title: ASSISTANT SUPERINTENDENT (Cont'd)

(3) Interview applicants and employees.
(4) Establish and maintain communications with employees and the public.

4. Specific Vocational Preparation
   a. Completion of operator training course or equivalent training and experience.
   b. Three to 5 years experience in wastewater treatment plant operation, depending upon size and complexity of plant and educational background.

5. Aptitudes-Relative to General Working Population
   a. Intelligence) Highest third excluding
   b. Verbal) top 10 per cent
   c. Numerical)
   d. Spatial)
   e. Form Perception)
   f. Clerical Perception)
   g. Motor Coordination) Middle third
   h. Finger Dexterity)
   i. Manual Dexterity)
   j. Eye-Hand-Foot Coordination)
   k. Color Discrimination)

6. Interests
   Prefer working with people in situations involving organization and supervision of varied activities.

7. Temperament
   Prefer situations involving the direction, control, and planning of an entire activity or the activity of others.

8. Physical Demands
   Light or sedentary work. Involves plant inspections and occasional medium work in emergency situations.

9. Working Conditions
   Indoor and outdoor. Exposure to weather, fumes, odors, dust and risk of bodily injury. Possible exposure to toxic conditions.

ENTRY SOURCES: Operations Supervisor, Shift Foreman, Chief Chemist, or Superintendent of considerably smaller plant.

PROGRESSION TO: Superintendent

OCCUPATION DESCRIPTION

Title: CLERK TYPIST, WASTEWATER TREATMENT PLANT

JOB DESCRIPTION

Performs any combination of following tasks and/or other clerical duties: Operates typewriter and other standard office machines and equipment; including adding machine, calculator, and duplicating machine. Serves as secretary to superintendent. Acts as receptionist. Responsible for personal work determination in accordance with established precedent or policy. Sets up simple office routines and filing systems. Minor supervisory responsibilities. Composes routine correspondence. Answers telephone and handles routine inquiries from public. Typing includes tables, reports, requisitions, forms, and other material from copy, draft, or dictating machines; frequently involving judgment regarding format or information to be included. Clerical duties include maintaining financial records not requiring technical bookkeeping skills. Duties ordinarily include posting, filing, sorting, and other routine clerical functions.

QUALIFICATIONS PROFILE

1. Formal Education
   High school graduate or equivalent, including or supplemented by courses in typing and other commercial subjects.

2. General Requirements
   a. Considerable knowledge of modern office methods and procedure.
   b. Knowledge of business English, spelling and arithmetic.
   c. Ability to operate standard office equipment and type minimum of 40 words per minute.
   d. Ability to maintain records and prepare reports.
   e. Ability to deal effectively with public by telephone and in person.
   f. Ability to exercise independent judgment.

3. General Educational Development
   a. Reasoning
      Apply common sense understanding to carry out general instructions.
   b. Mathematical
      Make arithmetical calculations involving percentages and decimals.

Title: CLERK TYPIST (Cont'd)

- c. Language
  - Ability to transcribe dictation, make appointments and handle routine correspondence.

4. Specific Vocational Preparation
   - a. Commercial courses in high school or business school.
   - b. Minimum one year progressively responsible general office experience, including typing and operation of office equipment.

5. Aptitudes - Relative to General Working Population
   - a. Intelligence)
   - b. Verbal)
   - c. Numerical) Middle third
   - d. Spatial)
   - e. Form Perception)
   - f. Clerical Perception)
   - g. Motor Coordination) Upper third excluding
   - h. Finger Dexterity) top 10 per cent
   - i. Manual Dexterity)
   - j. Eye-Hand-Foot Coordination)
   - k. Color Discrimination) Middle third

6. Interests
   - Prefer activities of a concrete, organized nature involving business contact with people.

7. Temperament
   - Worker must adjust to situations involving a variety of duties characterized by frequent change.

8. Physical Demands
   - Sedentary work.

9. Working Conditions
   - Inside work. No adverse conditions except possible exposure to odors.

ENTRY SOURCES: Employment agencies, general public.

PROGRESSION TO: Progress in grade only.

OCCUPATION DESCRIPTION

Title: OPERATIONS SUPERVISOR, WASTEWATER TREATMENT PLANT

JOB DESCRIPTION

Supervises and coordinates activities of plant operators, laborers, custodians, and other plant personnel. Prepares work schedules, subject to approval of superintendent or assistant superintendent. Analyzes recording instrument readings and laboratory test results; adjusts various plant processes accordingly. Prepares reports and maintains records. Inspects plant to determine efficiency of operation, cleanliness, and maintenance requirements. Determines remedial action in emergencies. Conducts training program. Requisitions chemicals and supplies. Performs duties of assistant superintendent in his absence.

QUALIFICATIONS PROFILE

1. Formal Education
   High school graduate or equivalent. College courses in engineering or chemistry highly desirable.

2. General Requirements
   a. Knowledge of processes and equipment involved in wastewater treatment.
   b. Ability to direct and evaluate operation of plant.
   c. Ability to handle emergencies.
   d. Ability to train and supervise plant operators.
   e. Ability to prepare routine operation reports and maintain records.

3. General Educational Development
   a. Reasoning
      (1) Apply principles of wastewater treatment to solve practical operational problems.
      (2) Interpret a variety of instructions in written, oral, diagrammatic, or schedule form.
   b. Mathematical
      Perform ordinary arithmethical, algebraic, and geometric procedures in standard, practical applications.
   c. Language
      (1) Write or assist in preparation of operation reports.
      (2) Establish and maintain communications with employees and superiors.

Title: OPERATIONS SUPERVISOR (Cont'd)

4. Specific Vocational Preparation
   - a. Completion of operator training course or equivalent in training and experience.
   - b. One to 5 years experience in wastewater treatment plant operation, depending upon size and complexity of plant. Supervisory experience highly desirable.

5. Aptitudes - Relative to General Working Population
   - a. Intelligence)
   - b. Verbal)
   - c. Numerical)
   - d. Spatial)
   - e. Form Perception)
   - f. Clerical Perception) Middle third
   - g. Motor Coordination)
   - h. Finger Dexterity)
   - i. Manual Dexterity)
   - j. Eye-Hand-Foot Coordination)
   - k. Color Discrimination)

6. Interests

   Prefer activities involving supervision of varied activities of a routine, concrete, organized nature.

7. Temperament

   Worker must adjust to situations involving the direction and planning of activities of others.

8. Physical Demands

   Light work. May occasionally engage in medium work during emergencies.

9. Working Conditions

   Both inside and outside. Exposed to weather, fumes, odors, dust, and risk of bodily injury. May be exposed to toxic conditions.

ENTRY SOURCES: Shift Foreman or Operator II, depending on size and complexity of plant.

PROGRESSION TO: Assistant Superintendent or Superintendent.

OCCUPATION DESCRIPTION

Title: SHIFT FOREMAN, WASTEWATER TREATMENT PLANT

JOB DESCRIPTION

Supervises operation of plant, under general direction of superiors. Performs duties of operations or maintenance supervisor in their absence. Supervises, instructs, and assigns specific duties to shift workers. Reviews and evaluates work performance. Participates in training programs. Inspects plant equipment and processes regularly. Analyzes instrument readings and laboratory test results. Determines site and causes of any malfunctions. Orders, supervises, or participates in required adjustments or repairs. Maintains and evaluates operating records. Replaces operator or maintenance worker during emergency situations. Communicates with other shift foremen regarding plant conditions.

QUALIFICATIONS PROFILE

1. Formal Education
   High school graduate or equivalent training and experience. Chemistry, science, and mechanical subjects highly desirable.

2. General Requirements
   a. Knowledge of processes and equipment involved in wastewater treatment.
   b. Ability to direct and evaluate operation of plant.
   c. Ability to supervise and train shift workers.
   d. Ability to react promptly and efficiently to emergencies.
   e. Ability to maintain and evaluate records.
   f. Ability to perform operation and maintenance duties if required.

3. General Educational Development
   a. Reasoning
      (1) Apply knowledge of wastewater treatment to solve practical problems.
      (2) Interpret a variety of written and oral instructions.
   b. Mathematical
      Perform ordinary arithmetical, algebraic, and geometric procedures in standard, practical applications.

Title: SHIFT FOREMAN (Cont'd)

- c. Language
  - (1) Establish and maintain communications with superiors and employees, including training and operating instructions.
  - (2) Prepare or assist in preparation of various operating reports, as required.
  - (3) Interpret technical manuals, drawings, specifications, blueprints and layouts.

4. Specific Vocational Preparation
   - a. Completion of operator training course or equivalent training and experience.
   - b. State operator certification, if applicable.
   - c. One to 3 years experience in wastewater treatment plant operation depending upon size and complexity of plant and worker's experience and training.

5. Aptitudes - Relative to General Working Population
   - a. Intelligence)
   - b. Verbal)
   - c. Numerical)
   - d. Spatial)
   - e. Form Perception)
   - f. Clerical Perception) Middle third
   - g. Motor Coordination)
   - h. Finger Dexterity)
   - i. Manual Dexterity)
   - j. Eye-Hand-Foot Coordination)
   - k. Color Discrimination)

6. Interest

   Prefer activities involving supervision of varied activities of a routine, concrete, organized nature.

7. Temperaments

   Worker must adjust to situations involving the direction and planning of activities of others.

8. Physical Demands

   Light work. May occasionally be required to engage in medium work involving climbing, balancing, reaching and handling.

9. Working Conditions

   Both inside and outside. Exposed to weather, fumes, odors, dust, and risk of bodily injury. May be exposed to toxic conditions.

Title: SHIFT FOREMAN (Cont'd)

ENTRY SOURCES:	Operator II with sufficient experience. Other smaller plants.
PROGRESSION TO:	Operations Supervisor, Assistant Superintendent, or Superintendent depending on size of plant.

OCCUPATION DESCRIPTION

Title: OPERATOR II, WASTEWATER TREATMENT PLANT

JOB DESCRIPTION

Performs any combination of following tasks pertinent to controlling operation of plant: Operates treatment facilities to control flow and processing of wastewater, sludge, and effluent. Monitors gages, meters, and control panels. Observes variations in operating conditions and interprets meter and gage readings and test results to determine processing requirements. Operates valves and gates either manually or by remote control; starts and stops pumps, engines and generators to control and adjust flow and treatment processes. Maintains shift log and records meter and gage readings. Extracts samples and performs routine laboratory tests and analyses. Performs routine maintenance functions and custodial duties. Operates and maintains power generating equipment and incinerators. Classified by titles such as Pumping Station Operator or Digestor Operator when performing specialized activities only. Makes operating decisions in absence of supervisory personnel.

QUALIFICATIONS PROFILE

1. Formal Education
   High school graduate or equivalent training and experience.
2. General Requirements
   a. Knowledge of processes and equipment involved in wastewater treatment.
   b. Ability to maintain and evaluate records.
   c. Ability to perform all required duties.
   d. Ability to maintain working relationship with other shift workers.
3. General Educational Development
   a. Reasoning
      (1) Apply knowledge of wastewater treatment to solve practical problems.
      (2) Interpret a variety of written and oral instructions.
   b. Mathematical
      Perform ordinary arithmetical and algebraic procedures in standard, practical applications.

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Title: OPERATOR II (Cont'd)

c. Language
  (1) Establish and maintain communications with superiors and co-workers.
  (2) Ability to comprehend oral and written instructions, record information, and request supplies and work materials orally or in writing.

4. Specific Vocational Preparation
  a. Completion of operator training course or equivalent training and experience.
  b. State operator certification, if applicable.
  c. Three to 12 months experience in wastewater treatment plant, depending upon formal training and prior experience.

5. Aptitudes - Relative to General Working Population
  a. Intelligence)
  b. Verbal)
  c. Numerical)
  d. Spatial)
  e. Form Perception)
  f. Clerical Perception) Middle third
  g. Motor Coordination)
  h. Finger Dexterity)
  i. Manual Dexterity)
  j. Eye-Hand-Foot Coordination)
  k. Color Discrimination)

6. Interests
  Prefer activities of a routine, concrete, organized nature; dealing with things and objects.

7. Temperament
  Worker must adjust to situations involving a variety of duties, including evaluation of information against measurable criteria and precise attainment of set limits or standards.

8. Physical Demands
  Medium work; involving climbing, balancing, stooping, kneeling, crouching, reaching, handling, fingering, talking, hearing, visual acuity, depth perception, and color vision.

9. Working Conditions
  Both inside and outside. Exposed to weather, fumes, odors, and dust. May be exposed to toxic conditions. Definite risk of bodily injury.

Title: OPERATOR II (Cont'd)

ENTRY SOURCES: Operator I.

PROGRESSION TO: Shift Foreman or Operations Supervisor.

OCCUPATION DESCRIPTION

Title: OPERATOR I, WASTEWATER TREATMENT PLANT

JOB DESCRIPTION

Assists Operator II in performance of any combination of following tasks pertinent to controlling operation of plant or performs various tasks as directed: Operates treatment facilities to control flow and processing of wastewater, sludge, and effluent. Monitors gages, meters, and control panels. Observes variations in operating conditions and interprets meter and gage readings and test results to determine processing requirements. Operates valves and gates either manually or by remote control; starts and stops pumps, engines, and generators to control and adjust flow and treatment processes. Maintains shift log and records meter and gage readings. Extracts samples and performs routine laboratory tests and analyses. Performs routine maintenance functions and custodial duties. Operates and maintains power generating equipment and incinerators. Classified by title such as Pumping Station Operator I or Digester Operator I when performing specialized activities only.

QUALIFICATIONS PROFILE

1. Formal Education
   High school graduate or equivalent training and experience.

2. General Requirements
   a. Ability to learn operation of plant processes and equipment.
   b. Ability to maintain and evaluate simple records.
   c. Ability to maintain working relationship with other shift workers.

3. General Educational Development
   a. Reasoning
      Apply common sense understanding to carry out written, oral, or diagrammatic instructions. Deal with problems involving concrete variables in or from standardized situations.
   b. Mathematical
      Perform ordinary arithmetical calculations.
   c. Language
      Ability to comprehend oral and written instructions, record information, and request supplies and work materials orally or in writing.

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Title: OPERATOR I (Cont'd)

4. Specific Vocational Preparation

   On-the-job training from date of employment. Completion of an operator training course highly desirable. Previous experience as laborer or equipment operator in wastewater treatment plant also desirable.

5. Aptitudes - Relative to General Working Population

   a. Intelligence)
   b. Verbal)
   c. Numerical)
   d. Spatial) Lowest third excluding
   e. Form Perception) bottom 10 per cent
   f. Clerical Perception)
   g. Motor Coordination)
   h. Finger Dexterity)
   i. Manual Dexterity) Middle third
   j. Eye-Hand-Foot Coordination) Lowest third excluding bottom 10 per cent
   k. Color Discrimination) Middle third

6. Interests

   Preference for activities of a routine, concrete, organized nature; dealing with things and objects.

7. Temperament

   Worker must adjust to situations involving a variety of duties and evaluation of information against measurable criteria.

8. Physical Demands

   Medium work; involving climbing, balancing, stooping, kneeling, crouching, reaching, handling, fingering, talking, hearing, visual acuity, depth perception, and color vision.

9. Working Conditions

   Both inside and outside. Exposed to weather, fumes, odors, and dust. May be exposed to toxic conditions. Definite risk of bodily injury.

ENTRY SOURCES: Graduates of operator training courses, treatment plant laborers or equipment operators, general public.

PROGRESSION TO: Operator II.

OCCUPATION DESCRIPTION

Title: AUTOMOTIVE EQUIPMENT OPERATOR, WASTEWATER TREATMENT PLANT

JOB DESCRIPTION

Operates automotive equipment such as dump truck, tank truck, fork lift, or tractor to perform any combination of tasks such as following: Loads or assists in loading grit, sludge, or other disposable material. Hauls material from plant to disposal area. Unloads material at destination. Operates tractor to cut grass or weeds, bulldoze soil, or remove snow. Performs maintenance on vehicles.

QUALIFICATIONS PROFILE

1. Formal Education

   Elementary school graduate or equivalent. Mechanical courses at high school or trade school level desirable.

2. General Requirements
   - a. Valid operator's license for equipment to be operated.
   - b. Ability to perform routine maintenance on vehicles.
   - c. Ability to follow simple oral or written instructions.

3. General Educational Development
   - a. Reasoning

     Apply common sense understanding to carry out simple one or two-step instructions. Deal with standardized situations with occasional variables in or from these situations encountered on the job.
   - b. Mathematical

     Perform simple addition and subtraction, reading and copying of figures, or counting and recording.
   - c. Language

     Ability to learn job duties from oral and written instructions or demonstration, and to request supplies or work materials orally or in writing.

4. Specific Vocational Preparation

   Short demonstration and directions only. (Proper operators license prerequisite).

Title: AUTOMOTIVE EQUIPMENT OPERATOR (Cont'd)

5. Aptitudes - Relative to General Working Population
   a. Intelligence)
   b. Verbal)
   c. Numerical) Lowest third excluding
   d. Spatial) bottom 10 per cent
   e. Form perception)
   f. Clerical Perception)
   g. Motor Coordination) Middle third
   h. Finger Dexterity) Lowest third excluding bottom 10 per cent
   i. Manual Dexterity) Middle third
   j. Eye-Hand-Foot Coordination)
   k. Color Discrimination) Lowest third excluding bottom 10 per cent

6. Interests

   Preference for activities of a routine, concrete, organized nature; dealing with things and objects.

7. Temperament

   Worker must adjust to situations involving doing things only under specific instruction; working alone and apart in physical isolation from others although the activity may be integrated with that of others.

8. Physical Demands

   Light and medium work primarily limited to reaching, handling, visual acuity and depth perception.

9. Working Conditions

   Both inside and outside. Exposed to weather, fumes, odors, and dust. May be exposed to toxic conditions.

ENTRY SOURCES: Laborer or general public.

PROGRESSION TO: Operator I.

OCCUPATION DESCRIPTION

Title: MAINTENANCE SUPERVISOR, WASTEWATER TREATMENT PLANT

JOB DESCRIPTION

Supervises all preventive and corrective maintenance on plant and equipment. Plans, schedules, and directs maintenance of wide variety of specialized mechanical and electrical equipment plus buildings, structures, and grounds. Inspects plant frequently to ensure proper maintenance procedures are followed. Determines the necessity for and establishes long-range maintenance programs. Decides remedial action in emergency situations. Supervises and instructs maintenance personnel. Supervises installation and testing of new or rebuilt equipment. Supervises inspection of contracted maintenance work. Submits maintenance budget requests. Supervises maintenance records. Performs related work as required.

QUALIFICATIONS PROFILE

1. Formal Education

   High school or trade school graduate or equivalent in training and experience. College level engineering courses highly desirable.

2. General Requirements
   a. Ability and knowledge necessary to supervise maintenance and repair of plant equipment, buildings, structures and grounds.
   b. Ability to implement and initiate preventive maintenance programs.
   c. Ability to maintain records and prepare reports.

3. General Educational Development
   a. Reasoning

      Apply principles of logical thinking to define problems, collect data, establish facts, and draw valid conclusions. Interpret an extensive variety of technical instructions, in books, manuals, and mathematical or diagrammatic form. Deal with several abstract and concrete variables.

   b. Mathematical

      Perform ordinary arithmetical, algebraic, and geometric procedures in standard, practical applications.

   c. Language

      Interpret technical manuals as well as drawings and and specifications, such as layouts, blueprints, and schematic.

Title: MAINTENANCE SUPERVISOR, WASTEWATER TREATMENT PLANT (Cont'd)

4. Specific Vocational Preparation
    a. Three to 8 years experience in the maintenance and repair of mechanical and electrical equipment, depending on education and size and complexity of plant.
    b. Minimum one year supervisory experience.

5. Aptitudes - Relative to General Working Population
    a. Intelligence)
    b. Verbal)
    c. Numerical) Middle third
    d. Spatial)
    e. Form Perception)
    f. Clerical Perception)
    g. Motor Coordination)
    h. Finger Dexterity) Highest third excluding
    i. Manual Dexterity) top 10 per cent
    j. Eye-Hand-Foot Coordination)
    k. Color Discrimination) Middle third

6. Interests
    Preference for sientific and technical activities, concerned with people and the communication of ideas.

7. Temperament
    Worker must adjust to situations involving direction, control, and planning of an entire activity or the activities of others.

8. Physical Demands
    Sedentary or light work, requiring walking and standing. Occasional heavy lifting possible in emergencies.

9. Working Conditions
    Inside. Occasionally exposed to outside weather conditions. Frequently encounters wet environment, definite risk of bodily injury, fumes, odors, and toxic conditions.

ENTRY SOURCES: Mechanical Maintenance Foreman

PROGRESSION TO: Assistant Superintendent

OCCUPATION DESCRIPTION

Title: MECHANICAL MAINTENANCE FOREMAN, WASTEWATER TREATMENT PLANT

JOB DESCRIPTION

Supervises mechanical maintenance crew in performance of a wide variety of maintenance and repair tasks on machinery, equipment, buildings, structures, and grounds. Duties include any combination of tasks such as following: Assigns tasks to maintenance crew. Directs and/or participates in maintenance and repair tasks as required. Supervises and instructs maintenance personnel on routine and emergency tasks. Consults superiors regarding preventive maintenance program. Establishes and operates preventive program. Inspects plant and mechanical equipment for malfunctions and needed repairs. Determines repair methods. Consults with superior and/or manufacturer's representative on difficult or complicated repairs. Keeps maintenance records. Works with contractors.

QUALIFICATIONS PROFILE

1. Formal Education
   High school or trade school education or equivalent training and experience. Shop courses highly desirable.

2. General Requirements
   a. Ability and knowledge necessary to supervise and participate in maintenance of mechanical and electro-mechanical equipment, buildings, structures, and grounds.
   b. Ability to initiate and operate preventive maintenance programs.
   c. Ability to keep records.

3. General Educational Development
   a. Reasoning
      Apply principles of rational systems to solve practical problems and deal with a variety of concrete variables in situations where only limited standardization exists. Interpret a variety of instructions furnished in written, oral, diagrammatic, or schedule form.
   b. Mathematical
      Perform ordinary arithmetical, algebraic, and geometric procedures in standard, practical applications.

Title: MECHANICAL MAINTENANCE FOREMAN (Cont'd)

c. Language

Ability to interpret technical manuals, drawings and specifications, including layouts, blueprints, and schematics.

4. Specific Vocational Preparation
   a. Two to 5 years experience in the maintenance and repair of mechanical equipment and structures, depending on size and complexity of plant.

5. Aptitudes - Relative to General Working Population

a. Intelligence	Middle third
b. Verbal	
c. Numerical	
d. Spatial	
e. Form Perception	
f. Clerical Perception	
g. Motor Coordination	Highest third excluding top 10 per cent
h. Finger Dexterity	
i. Manual Dexterity	
j. Eye-Hand-Foot Coordination	
k. Color Discrimination	Lowest third excluding bottom 10 per cent

6. Interests

Preference for scientific and technical activities concerned with people and the communication of ideas.

7. Temperament

Worker must adjust to a variety of duties involving the direction, control, and planning of the activities of others.

8. Physical Demands

Light to medium work. Involves walking, standing, climbing, balancing, stooping, kneeling, crouching, reaching, handling, and feeling. May occasionally require heavy lifting.

9. Working Conditions

Both inside and outside. Exposed to weather, dampness, noise and vibration, fumes, odors, toxic conditions, dust, and risk of bodily injury.

ENTRY SOURCES: Maintenance Mechanic II

PROGRESSION TO: Maintenance Supervisor

OCCUPATION DESCRIPTION

Title: MAINTENANCE MECHANIC II, WASTEWATER TREATMENT PLANT

JOB DESCRIPTION

Performs preventive maintenance and repairs on mechanical and electromechanical machinery and equipment, under general direction of superior. Maintains buildings structures and grounds. Duties include any combination of tasks such as following: Lubricates equipment and checks for malfunctions. Replaces packing in pumps or valves. Replaces bearings in motors, pumps, and other equipment. Adjusts and cleans bar screens, comminutors, and weir plates. Cleans out pipes and performs other plumbing and pipefitting tasks as required. Uses gas and/or arc welding equipment to heat, cut, braze, or weld. Performs duties of electrician and/or painter in their absence. Installs and sets up new equipment. Assists in keeping maintenance records. Supervises, instructs, and inspects work of Mechanic I, Maintenance Helper, or Laborer to ensure proper performance of maintenance work or repairs. Performs general maintenance and repair tasks on buildings, structures, and grounds.

QUALIFICATIONS PROFILE

1. Formal Education
   High school or trade school graduate or equivalent training and experience.

2. General Requirements
   a. Thorough knowledge of wastewater treatment machinery and equipment, plus ability to perform necessary maintenance and repairs.
   b. Ability to handle variety of duties without close supervision.

3. General Educational Development
   a. Reasoning
      Apply common sense understanding to carry out instructions furnished in oral, written, or diagrammatic form.
   b. Mathematical
      Make arithmetical calculations involving fractions, decimals and percentages.
   c. Language
      Ability to interpret technical manuals, drawings and specifications, including layouts, blueprints and schematics.

Title: MAINTENANCE MECHANIC II (Cont'd)

4. Specific Vocational Preparation
   a. Vocational or technical school shop courses or equivalent in-plant or on-the-job training.
   b. Minimum 3 years experience in mechanical maintenance work.

5. Aptitudes - Relative to General Working Population
   a. Intelligence)
   b. Verbal)
   c. Numerical) Middle third
   d. Spatial)
   e. Form Perception)
   f. Clerical Perception) Lowest third excluding bottom 10 per cent
   g. Motor Coordination)
   h. Finger Dexterity) Highest third excluding
   i. Manual Dexterity) top 10 per cent
   j. Eye-Hand-Foot Coordination) Middle third
   k. Color Discrimination)

6. Interests

   Preference for scientific and technical activities dealing with things and objects.

7. Temperament

   Worker must adjust to a variety of duties, involving working alone and apart in physical isolation from others.

8. Physical Demands

   Medium work. Involves climbing, balancing, stooping, kneeling, crouching, reaching, handling, fingering, and feeling. Occasional heavy lifting possible in emergencies.

9. Working Conditions

   Both inside and outside. Exposed to weather, dampness, fumes, odors, dust, toxic conditions, and definite risk of bodily injury.

ENTRY SOURCES: Maintenance Mechanic I

PROGRESSION TO: Maintenance Foreman

OCCUPATION DESCRIPTION

Title: MAINTENANCE MECHANIC I, WASTEWATER TREATMENT PLANT

JOB DESCRIPTION

Performs or assists in performance of preventive maintenance and repairs on mechanical and electromechanical machinery and equipment, under direction of Mechanic II, Foreman, or Supervisor. Maintains buildings, structures, and grounds. Duties include any combination of tasks such as following: Lubricates motors and equipment and checks for malfunction. Replaces packing in pumps and valves. Replaces bearings in motors, pumps, and other equipment. Adjusts and cleans bar screens, comminutors, and weir plates. Installs and sets up new equipment. Cleans out pipes and performs other plumbing and pipefitting tasks as required. Uses gas and/or arc welding equipment to heat, cut, braze, or weld. Performs duties of electrician and/or painter in their absence. Assists Mechanic II and/or Foreman on difficult or highly complicated maintenance or repair tasks. Performs general maintenance and repair tasks on buildings, structures and grounds, including limited laboring and custodial tasks. Assists in keeping maintenance records.

QUALIFICATIONS PROFILE

1. Formal Education
   High school or trade school graduate or equivalent training and experience.

2. General Requirements
   a. General knowledge of wastewater treatment machinery and equipment, plus the ability to perform wide variety of maintenance and repair tasks.
   b. Ability to follow detailed and reasonably complicated instructions.

3. General Education Development
   a. Reasoning
      Apply common sense understanding to carry out instructions furnished in oral, written, and/or diagrammatic form.
   b. Mathematical
      Make arithmetic calculations involving fractions, decimals and percentages.
   c. Language
      Ability to interpret technical manuals, drawings and specifications, including layouts, blueprints and schematics.

Title: MAINTENANCE MECHANIC I (Cont'd)

4. Specific Vocational Preparation
    a. Vocational or technical school shop courses or equivalent in-plant or on-the-job training.
    b. Minimum 6 months experience in mechanical maintenance work.

5. Aptitudes - Relative to General Working Population
    a. Intelligence)
    b. Verbal)
    c. Numerical) Middle third
    d. Spatial)
    e. Form Perception)
    f. Clerical Perception) Lowest third excluding bottom 10 per cent
    g. Motor Coordination)
    h. Finger Dexterity) Highest third excluding
    i. Manual Dexterity) top 10 per cent
    j. Eye-Hand-Foot Coordination)
    k. Color Discrimination) Middle third

6. Interests
    Preference for technical activities dealing with things and objects.

7. Temperatment
    Worker must adjust to a variety of duties, involving working alone and apart in physical isolation from others.

8. Physical Demands
    Medium to heavy work. Involves lifting, climbing, balancing, stooping, kneeling, crouching, reaching, handling, fingering, and feeling.

9. Working Conditions
    Both inside and outside. Exposed to weather, dampness, fumes, odors, dust, toxic conditions, and definite risk of bodily injury.

ENTRY SOURCES: Trade school graduates. General public.

PROGRESSION TO: Maintenance Mechanic II.

OCCUPATION DESCRIPTION

Title: ELECTRICIAN II, WASTEWATER TREATMENT PLANT

JOB DESCRIPTION

Inspects, repairs, and maintains electrical and/or electronic operating and control systems, equipment, and fixtures; including instrumentation and heating and cooling systems. Exercises independent judgment in solving normal work problems under general supervision of maintenance supervisor or assistant superintendent, using standard and special electrical tools and equipment, such as volt-meters, ammeters, and synchroscopes. Duties include any combination of tasks such as following: Inspects, maintains and repairs wiring and lighting systems, electrical control equipment, meters, outlets, and panels. Installs new equipment. Interprets oral and written instructions, specifications, wiring diagrams and codes. Supervises Electrician I, Maintenance Helper, and/or Laborer. Establishes and operates scheduled maintenance program for plant equipment. Repairs electrical and electronic instruments. Keeps maintenance records. Prepares labor and material estimates.

QUALIFICATIONS PROFILE

1. Formal Education

   High school or electrical trade school graduate or equivalent training and experience. Engineering and electronics courses highly desirable.

2. General Requirements
   a. Thorough knowledge of electrical systems, equipment, and fixtures.
   b. Thorough knowledge of approved methods, practices, code requirements, and safety standards.
   c. Ability to perform limited supervisory duties and maintain satisfactory working relations with other employees.

3. General Education Development
   a. Reasoning
      (1) Apply principles of rational systems to solve practical problems and deal with a variety of concrete variables in situations where only limited standardization exists.
      (2) Interpret a variety of instructions furnished in written, oral, diagrammatic, or schedule form.
   b. Mathematical

      Perform ordinary arithmetical and algebraic procedures in standard, practical applications.

Title: ELECTRICIAN II (Cont'd)

c. Language
Comprehension and expression of a level to interpret technical manuals, including drawings and specifications, layouts, blueprints, and schematics.

4. Specific Vocational Preparation
a. Qualification equivalent to journeyman electrician, plus minimum 3 years practical experience, including maintenance and repair of equipment and systems found in wastewater treatment plant.
b. Completion of courses in electronic equipment maintenance or equivalent training and experience. Applies only to plants where electronic equipment is installed.

5. Aptitudes - Relative to General Working Population
a. Intelligence)
b. Verbal)
c. Numerical) Middle third
d. Spatial)
e. Form Perception)
f. Clerical Perception)
g. Motor Coordination)
h. Finger Dexterity) Highest third excluding
i. Manual Dexterity) top 10 per cent
j. Eye-Hand-Foot Coordination)
k. Color Distrimination) Middle third

6. Interests
Perference for technical activities carried on in relation to processes, machines, and techniques.

7. Temperament
Worker must adjust to situations involving a variety of duties, precise attainment of set limits, tolerances, or standards, and direction of the activities of others.

8. Physical Demands
Medium work. Involves climbing, balancing, stooping, kneeling, crouching and crawling, reaching, handling, fingering and feeling.

9. Working Conditions
Both inside and outside. Exposed to weather, noise and vibration, fumes, odors, toxic conditions, dust, poor ventilation, and definite risk of bodily injury.

Title: ELECTRICIAN II (Cont'd)

ENTRY SOURCES: Electrician I.

PROGRESSION TO: Maintenance Supervisor or Assistant Superintendent.

OCCUPATION DESCRIPTION

Title: ELECTRICIAN I, WASTEWATER TREATMENT PLANT

JOB DESCRIPTION

Participates in installation, maintenance, and repair of electrical systems, equipment, and fixtures. Assists Electrician II in particularly difficult or complicated tasks. Work is frequently performed independently, subject to inspection by superiors. Follows oral and written instructions including specifications, wiring diagrams, and codes. Duties include any combination of tasks such as following: Inspects, maintains, and repairs wiring and lighting systems, electrical control equipment, meters, outlets, and panels. Installs new equipment. Supervises maintenance helper and/or laborer. Repairs electrical instruments. Keeps maintenance records.

QUALIFICATIONS PROFILE

1. Formal Education
   High school or electrical trade school graduate or equivalent training and experience. Electronic courses desirable.

2. General Requirements
   a. Sound working knowledge of electrical systems, equipment, and fixtures.
   b. Thorough knowledge of approved methods, practices, code requirements, and safety standards.

3. General Educational Development
   a. Reasoning
      (1) Apply principles of rational systems to solve practical problems and deal with a variety of concrete variables in situations where only limited standardization exists.
      (2) Interpret a variety of instructions furnished in written, oral, diagrammatic, or schedule form.
   b. Mathematical
      Perform ordinary arithmetical and algebraic procedures in standard, practical applications.
   c. Language
      Comprehension and expression of a level to interpret technical manuals as well as drawings and specifications such as layouts, blueprints, and schematics.

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Title: ELECTRICIAN I (Cont'd)

4. Specific Vocational Preparation
   Qualification equivalent to journeyman electrician.

5. Aptitudes - Relative to General Working Population
   a. Intelligence)
   b. Verbal)
   c. Numerical) Middle third
   d. Spatial)
   e. Form Perception)
   f. Clerical Perception)
   g. Motor Coordination)
   h. Finger Dexterity) Highest third exclusive of
   i. Manual Dexterity) the top 10 per cent
   j. Eye-Hand-Foot Coordination)
   k. Color Discrimination) Middle third

6. Interests
   Preference for technical activities carried on in relation to processes, machines, and techniques.

7. Temperament
   Worker must adjust to situations involving a variety of duties characterized by frequent change, and requiring precise attainment of set limits, tolerances, or standards.

8. Physical Demands
   Medium work. Involves climbing, balancing, stooping, kneeling, crouching and crawling, reaching, handling, fingering, feeling, and seeing.

9. Working Conditions
   Both inside and outside. Exposed to weather conditions, noise and vibration, fumes, odors, toxic conditions, dust, poor ventilation, and definite risk of bodily injury.

ENTRY SOURCES: Trade school and electrical apprentice program graduates. Qualified electricians.

PROGRESSION TO: ELECTRICIAN II.

OCCUPATION DESCRIPTION

Title: MAINTENANCE HELPER, WASTEWATER TREATMENT PLANT

JOB DESCRIPTION

Assists maintenance mechanics in maintaining and repairing equipment, machinery, buildings, and grounds. Duties include any combination of tasks such as following: Cleans and lubricates pumps, motors, and related equipment. Assists in removing, repairing, and replacing equipment as directed. Performs routine building maintenance work. Performs simple repairs and adjustments to equipment. Keeps simple records. Carries or holds materials, supplies, or tools to assist mechanics, electricians, or painters. Performs laborer tasks as required.

QUALIFICATIONS PROFILE

1. Formal Education
   High school or trade school graduate or equivalent training and experience highly desirable.

2. General Requirements
   a. Basic mechanical aptitude.
   b. Ability to use a variety of hand and power tools and equipment.

3. General Educational Development
   a. Reasoning
      Apply common sense understanding to carry out detailed but uninvolved written or oral instructions.
   b. Mathematical
      Make arithmetical calculations involving fractions, decimals, and percentages.
   c. Language
      Ability to understand oral and written instructions.

4. Specific Vocational Preparation
   Vocational or high school shop courses or equivalent on-the-job training.

5. Aptitudes - Relative to General Working Population
   a. Intelligence)
   b. Verbal)
   c. Numerical) Lowest third excluding
   d. Spatial) bottom 10 per cent
   e. Form Perception)
   f. Clerical Perception)

Title: MAINTENANCE HELPER (Cont'd)

g. Motor Coordination)
h. Finger Dexterity)
i. Manual Dexterity) Middle third
j. Eye-Hand-Foot Coordination)
k. Color Discrimination)

6. Interests
Preference for activities dealing with things and objects.

7. Temperament
Worker must adjust to situations involving doing things only under specific instruction, allowing little or no room for independent action or judgment in working out job problems.

8. Physical Demands
Heavy to very heavy work. Involves lifting heavy objects, climbing, balancing, stooping, kneeling, crouching, crawling, reaching, and handling.

9. Working Conditions
Both inside and outside work. Exposed to weather. Subject to noise and vibration, fumes, odors, toxic conditions, dust, poor ventilation, and definite risk of bodily injury.

ENTRY SOURCES: Laborers. High school or vocational school graduates. General public.

PROGRESSION TO: Mechanic I.

OCCUPATION DESCRIPTION

Title: LABORER, WASTEWATER TREATMENT PLANT

JOB DESCRIPTION

Performs any combination of tasks such as following: Cleans equipment such as bar screens, comminutors, and weirs. Lubricates machinery. Drives, loads and unloads trucks; spreads sand, gravel, and dirt. Paints (rough) and performs other minor maintenance. Digs and refills ditches. Cleans drains, ditches, and culverts. Cuts grass, weeds, and brush; trims trees and bushes; rakes grass, leaves, and trash; seeds and cares for lawn and ornamental plantings. Removes snow and ice from walkways, driveways, and equipment. Collects and disposes of trash. Washes and cleans vehicles, tools, and equipment. Carries or holds material, supplies, or tools to assist operating and/or maintenance personnel.

QUALIFICATIONS

1. Formal Education
   Elementary school education desirable. Must be able to speak, read, and write English.

2. General Requirements
   a. Ability to understand and carry out oral and written instructions.
   b. Ability to perform strenuous manual labor under adverse weather conditions.
   c. Ability to use a variety of hand and power tools and equipment.
   d. Valid vehicle operator's license, if required.

3. General Educational Development
   a. Reasoning
      Apply common sense understanding to carry out simple instructions.
   b. Mathematical
      Perform simple addition and subtraction for counting and recording purposes.
   c. Language
      Ability to learn job duties from oral instructions or demonstrations and request supplies and materials orally or in writing.

4. Specific Vocational Preparation
   On-the-job training or previous experience as a laborer.

Title: LABORER (Cont'd)

5. Aptitudes - Relative to General Working Population
    a. Intelligence)
    b. Verbal)
    c. Numerical) Lowest third excluding
    d. Spatial) bottom 10 per cent
    e. Form Perception)
    f. Clerical Perception)
    g. Motor Coordination)
    h. Finger Dexterity)
    i. Manual Dexterity) Middle third
    j. Eye-Hand-Foot Coordination)
    k. Color Discrimination)

6. Interests

   Preference for activities dealing with things and objects.

7. Temperament

   Worker must adjust to situations involving working only under specific instruction, allowing little or no room for independent action or judgment in working out job problems.

8. Physical Demands

   Heavy to very heavy work. Involves lifting heavy objects, climbing, balancing, stooping, kneeling, crouching, crawling, reaching, and handling

9. Working Conditions

   Primarily outside. No protection from weather. Subject to noise and vibration, hazards, fumes, odors, and toxic conditions.

ENTRY SOURCES: Unskilled labor market.

PROGRESSION TO: Equipment Operator or Operator I.

OCCUPATION DESCRIPTION

Title: PAINTER, WASTEWATER TREATMENT PLANT

JOB DESCRIPTION

Performs all types of painting work, including any combination of tasks such as following, under general supervision of Maintenance Foreman or Shift Foreman: Prepares various surfaces for painting by washing, scraping, burning, sanding, sand-blasting or other means as necessary. Mixes, matches, and blends various paints, enamels, lacquers, varnishes, stains and special protective coatings to achieve desired color, consistency, and drying properties. Caulks, putties, cements, or plasters holes and cracks. Cuts and replaces glass in windows and doors. Erects and uses ladders, scaffolding, and swinging stage equipment as required. Paints buildings, structures, equipment, and furniture using brush, roller, spray gun or other applicator. Prepares wall and hangs paper or other wall covering material. Performs simple sign-painting, using stencils. Requisitions material and equipment. Cleans and stores tools and equipment. Cleans work site or arranges for laborer to clean.

QUALIFICATIONS PROFILE

1. Formal Education
   Elementary school education desirable. Must be able to read, write, and understand basic arithmetic.

2. General Requirements
   a. Knowledge of standard practices, materials, tools, and techniques of painting trade.
   b. Ability to use and experience in using painting tools.
   c. Ability to mix, match, and blend paint to desired color, consistency, and drying properties.
   d. Ability to estimate materials and time required to complete various tasks.

3. General Educational Development
   a. Reasoning
      Apply common sense understanding to carry out simple instructions.
   b. Mathematical
      Perform simple addition and subtraction for counting, measuring, and recording purposes.
   c. Language
      Ability to learn job duties from oral instructions or demonstration and request supplies and materials orally or in writing.

Title: PAINTER (Cont'd)

4. Specific Vocational Preparation
    a. Completion of apprentice painter program or equivalent in training and experience.
    b. Minimum one year experience at level equivalent to journeyman painter on similar plant work.

5. Aptitudes - Relative to General Working Population
    a. Intelligence)
    b. Verbal)
    c. Numerical) Middle third
    d. Spatial)
    e. Form Perception)
    f. Clerical Perception) Lowest third excluding bottom 10 per cent
    g. Motor Coordination) Highest third excluding top 10 per cent
    h. Finger Dexterity) Middle third
    i. Manual Dexterity)
    j. Eye-Hand-Foot Coordination) Highest third excluding
    k. Color Discrimination) top 10 per cent

6. Interests

    Preference for activities dealing with things and objects.

7. Temperament

    Worker must adjust to working only under specific instruction.

8. Physical Demands

    Medium work. Requires climbing, balancing, stooping, kneeling, crouching, reaching, handling, and good color vision.

9. Working Conditions

    Both inside and outside. Subject to fumes, odors, toxic conditions, dust, and poor ventilation. Definite risk of bodily injury.

ENTRY SOURCES: Qualified painters.

PROGRESSION TO: Progress in grade only.

OCCUPATION DESCRIPTION

Title: STOREKEEPER, WASTEWATER TREATMENT PLANT

JOB DESCRIPTION

Requisitions, receives, stores, and issues materials, supplies, tools, and equipment. Maintains inventory records and controls. Duties include any combination of tasks such as following: Inspects incoming stock to verify quantity, quality, and adherence to specifications. Identifies and stores material. Fills orders and issues supplies from stock. Prepares periodic or perpetual inventory. Requisitions replacement quantities of stock items as necessary. Compiles records and reports of material used, spoilage or other loss, inventory adjustments, and refusal of shipments. Recommends changes in established procedures. Determines methods of storage, identification, and location of stock. Divides stock quantities into portions to fill orders.

QUALIFICATIONS PROFILE

1. Formal Education
   High school education or equivalent in training and experience.

2. General Requirements
   a. Knowledge of procedures used in the receipt, storage, handling, and control of merchandise.
   b. Ability to maintain inventory and stock control records.

3. General Educational Development
   a. Reasoning
      Apply common sense understanding to carry out oral, written, or diagrammatic instructions. Deal with problems involving several concrete variables in or from standardized situations.
   b. Mathematical
      Make arithmetical calculations involving fractions, decimals, and percentages.
   c. Language
      Ability to maintain adequate incoming stock, handling, storage, and inventory records.

4. Specific Vocational Preparation
   Six months to one year experience in storekeeping or similar work.

Title: STOREKEEPER (Cont'd)

5. Aptitudes - Relative to General Working Population
    a. Intelligence)
    b. Verbal)
    c. Numerical)
    d. Spatial) Middle third
    e. Form Perception)
    f. Clerical Perception)
    g. Motor Coordination)
    h. Finger Dexterity) Lowest third, excluding
    i. Manual Dexterity) bottom 10 per cent
    j. Eye-Hand-Foot Coordination)
    k. Color Discrimination)

6. Interests

Prefer routine, concrete, organized activities.

7. Temperament

Worker must adjust to working alone and in physical isolation from others, although the activity may be integrated with that of others.

8. Physical Demands

Medium work. Involves frequent lifting, stooping, reaching, and handling.

9. Working Conditions

Inside.

ENTRY SOURCES: Experienced stock clerks, receiving clerks, or storekeepers.

PROGRESSION TO: Progress in grade only.

OCCUPATION DESCRIPTION

Title: CUSTODIAN, WASTEWATER TREATMENT PLANT

JOB DESCRIPTION

Cleans all or designated portions of wastewater treatment plant and grounds. Performs any combination of tasks such as following, in accordance with established procedures, subject to inspection for adherence to required standards of cleanliness and compliance with instructions: Sweeps, mops, waxes, and polishes floors; washes walls and woodwork; dusts furniture, piping, valves, etc. Washes and polishes windows and metal surfaces. Cleans restrooms and maintains supplies. Empties wastecans and ashtrays. Performs general custodial duties on grounds, including picking up litter and sweeping walks. May shovel snow and cut grass. Adjusts heat and ventilating controls. Reports any repairs or adjustments required. Acts as watchman. Washes and polishes cars and trucks.

QUALIFICATIONS

1. Formal Education
   Elementary school education desirable. Must be able to speak, read, and write English and understand basic arithmetic.

2. General Requirements
   a. Knowledge of cleaning materials, equipment, methods and procedures.
   b. Ability to use and maintain a variety of cleaning equipment.
   c. Ability to understand and carry out oral and written instructions.

3. General Educational Development
   a. Reasoning
      Apply common sense understanding to carry out simple instructions.
   b. Mathematical
      Perform simple addition and subtraction for counting and recording purposes.
   c. Language
      Ability to learn job duties from oral instructions or demonstrations and request supplies and materials orally or in writing.

4. Specific Vocational Preparation
   On-the-job training or previous experience in custodial work.

Title: CUSTODIAN (Cont'd)

5. Aptitudes - Relative to General Working Population
    a. Intelligence)
    b. Verbal)
    c. Numerical)
    d. Spatial)
    e. Form Perception) Lowest third, excluding
    f. Clerical Perception) bottom 10 per cent
    g. Motor Coordination)
    h. Finger Dexterity)
    i. Manual Dexterity)
    j. Eye-Hand-Foot Coordination)
    k. Color Discrimination)

6. Interests
    Prefer dealing with things and objects.

7. Temperament
    Worker must adjust to repetitive operations carried out according to set procedures.

8. Physical Demands
    Medium work; involving climbing, balancing, stooping, kneeling, crouching, and reaching.

9. Working Conditions
    Both inside and outside. Exposed to weather, fumes, odors, toxic conditions, and risk of bodily injury.

ENTRY SOURCES: General public.

PROGRESSION TO: Equipment Operator or Operator I.

OCCUPATION DESCRIPTION

Title: CHEMIST, WASTEWATER TREATMENT PLANT

JOB DESCRIPTION

Supervises and performs specialized and complex chemical, bacteriological and physical tests and analyses of raw, partially treated, and treated wastewater and byproducts to determine efficiency of plant processes and insure that plant effluent meets local, state, and federal requirements. Conducts or supervises less complex routine tests. Supervises collection of laboratory samples. When laboratory technicians are present, supervises technicians and provides routine procedures to be followed. Evaluates and interprets test results, establishes test priorities, and prepares reports. Assembles data, maintains records, and prepares periodic reports. Sets up pilot processes when conducting research on improved procedures. Provides direct or indirect instructions to operating personnel regarding chemical requirements and adjustments, changes, or additions to various treatment processes.

QUALIFICATIONS PROFILE

1. Formal Education
   College degree in chemistry or high school graduate plus college-level courses in chemistry, biology, and bacteriology.

2. General Requirements
   a. Thorough knowledge of wastewater treatment processes and chemical, biological, or bacteriological action involved in each process.
   b. Thorough knowledge of pertinent local, state, and federal regulations and requirements.
   c. Ability to work on own initiative and establish proper testing procedures.
   d. Ability to organize and interpret data and transmit instructions.

3. General Educational Development
   a. Reasoning
      Apply principles of chemistry, biology, and bacteriology to solve problems related to wastewater treatment and deal with a variety of concrete variables; interpret a variety of written, oral, and diagrammatic instructions.

Title: CHEMIST (Cont'd)

b. Mathematical
Perform ordinary arithmetical and algebraic procedures in standard, practical applications may require knowledge of higher mathematics.

c. Language
Ability to evaluate and interpret technical data, prepare reports, and maintain communications with supervisory personnel and co-workers.

d. Science
Understand chemical, biological, and bacteriological processes pertinent to wastewater treatment, and possess sound knowledge of problems and processes involved.

4. Specific Vocational Preparation
Laboratory experience in a position of responsibility. Six to 18 months on-the-job training or prior experience in wastewater treatment plant operations, depending upon education, size of plant, and complexity of treatment.

5. Aptitudes - Relative to General Working Population
a. Intelligence)
b. Verbal) Highest third excluding
c. Numerical) top 10 per cent
d. Form Perception) Middle third
e. Clerical Perception) Highest third excluding top 10 per cent
f. Motor Coordination)
g. Finger Dexterity) Middle third
h. Manual Dexterity)
i. Eye-Hand-Foot Coordination)
j. Color Discrimination) Highest third excluding top 10 per cent

6. Interest
Prefer scientific and technical activities.

7. Temperament
Worker must adjust to situations involving evaluation of information against measurable criteria.

8. Physical Demands
Sedentary or light work. May require considerable standing.

9. Working Conditions
Inside. May be subject to fumes, odors, and toxic conditions.

Title: CHEMIST (Cont'd)

ENTRY SOURCES:	Laboratory technicians with proper qualifications. Chemists in smaller or less complex plants. Other qualified chemists.
PROGRESSION TO:	Assistant Superintendent or Superintendent.

OCCUPATION DESCRIPTION

Title: LABORATORY TECHNICIAN, WASTEWATER TREATMENT PLANT

JOB DESCRIPTION

Performs any combination of routine laboratory tasks such as following: Collects samples of plant influent, partially treated wastewater, sludge, effluent, and other byproducts. Assembles instruments and equipment for analytical or research work. Prepares chemical and bacteriological media, stains, reagents, and test solutions routinely used in laboratory. Operates equipment and conducts tests as directed. Maintains test result records, prepares data sheets. Prepares or assists in preparation of reports. Cleans, maintains, and stores instruments and equipment. Maintains inventory and orders supplies. Performs custodial duties in laboratory. Operates laboratory in small primary treatment or trickling filter plant in absence of chemist.

QUALIFICATIONS PROFILE

1. Formal Education
   High school graduate or equivalent. Courses in chemistry and biology highly desirable.

2. General Requirements
   a. Knowledge of basic principles of chemical, physical, and bacteriological examination and treatment of wastewater, sludge, effluent, and by-products.
   b. Knowledge of standard laboratory principles, technology, and equipment.
   c. Ability to follow prescribed methods and processes and maintain proper records.

3. General Educational Development
   a. Reasoning
      Apply common sense understanding to carry out instructions in written, oral, or diagrammatic form and deal with problems involving a few concrete variables in or from standardized situations.
   b. Mathematics
      Make arithmetical calculations involving fractions, decimals, and percentages.
   c. Language
      Ability to learn job duties from oral instructions or demonstration, fill in report forms and accurately record data.

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Title: LABORATORY TECHNICIAN (Cont'd)

d. Science
Understand basic chemical, bacteriological, and biological processes; standard laboratory principles, methods, and equipment.

4. Specific Vocational Preparation
One to 3 months on-the-job training or experience in laboratory work of a similar nature.

5. Aptitudes - Relative to General Working Population
a. Intelligence)
b. Verbal)
c. Numerical)
d. Spatial) Middle third
e. Form Perception)
f. Clerical Perception)
g. Motor Coordination)
h. Finger Dexterity) Highest third excluding top
i. Manual Dexterity) 10 per cent
j. Eye-Hand-Foot Coordination) Middle third
k. Color Discrimination) Highest third exlcuding top
10 per cent

6. Interests
Prefer scientific and technical activities of a routine, concrete, organized nature; dealing with things and objects.

7. Temperatment
Worker must adjust to situations involving evaluation of information against measurable criteria and repetitive operations carried out according to set procedures or sequences.

8. Physical Demands
Light work. Requires walking and standing to a significant degree, and frequent lifting of objects weighing up to 10 pounds.

9. Working Conditions
Inside work. Subject to fumes, odors, and toxic conditions.

ENTRY SOURCES: High school graduates. General public.

PROGRESSION TO: Chemist.

PART FOUR - WASTEWATER STABILIZATION PONDS

SECTION I

GENERAL CONSIDERATIONS

Part Four presents a basis and method for estimating the initial investment cost, and the operation and maintenance cost, for wastewater stabilization ponds used as the only process to treat wastewater. Relationships of estimated construction costs and operation and maintenance costs to appropriate capacity parameters are presented for stabilization ponds having a treatment capacity up to 10 million gallons per day. A basis and method for estimating total manpower requirements and staffing is included. Occupation descriptions applicable to personnel commonly required for operation and maintenance of wastewater stabilization ponds are also included.

A stabilization pond, as referred to in this report, is defined as a type of oxidation pond in which biological oxidation of organic matter is effected by natural or artificially accelerated transfer of oxygen from air to the wastewater.

The estimating data for stabilization ponds should be considered as applying to average situations in the coterminus United States. Judgment must be carefully exercised by the estimator in determining the applicability of this data to any particular location. The estimating data and methods presented cannot be used as a substitute for cost estimating based on detailed knowledge of conditions applicable to a specific location.

Estimates of construction costs are developed on the basis of data available from actual costs of projects in the experience of Black & Veatch, and costs of facilities investigated in the field in the course of this study.

The experience data used as a basis for developing construction cost curves cover a wide geographic area and include projects of varied construction conditions. The actual costs of projects have been trended to a common cost level, using the national average Water Quality Office - Sewage Treatment Plant (WQO-STP) Cost Index, as of January, 1971. The cost index was 150.60 at that time.

Estimates of construction costs presented are representative of national average price levels as of January 1971. If the estimating data are to represent costs in a particular area at a different date, they must be adjusted accordingly. The cost adjustment can be based upon the WQO-STP index which permits comparison of price levels at differing locations and dates. The adjustment should be made to reflect price levels expected to prevail throughout the anticipated project construction period.

Operation and maintenance cost data, and manpower requirements associated with stabilization ponds, are developed on the basis of data collected during field investigation of stabilization ponds. A total of 38 stabilization ponds, located in 27 communities, were investigated to obtain background data on operating experience for this report. The geographic location of the communities visited, and the type of stabilization ponds from which data were collected, are identified in Table 16. The ponds investigated vary in size from 7 to 280 acres.

TABLE 16

WASTEWATER STABILIZATION PONDS INVESTIGATED

Location of Ponds	Number of Ponds Investigated	Type of Stabilization Pond		Water Surface Area Acres
		Nonaerated	Wholly or Partly Aerated	
Arizona:				
Chandler	1		1	36
Kearney	1		1	7
Safford	1		1	9
Arkansas:				
Clarksville	1	1		75
El Dorado	5	5		15,15,21,31,65
Georgia:				
Carrollton	1		1	35
Monroe	3	1	2	8,20,49
Savannah	2		2	10,14
Kansas:				
Iola	1	1		101
Paola	1	1		66
Louisiana:				
Jonesboro	3	3		11,14,24
Minden	1	1		23
Missouri:				
Webb City	2	2		19,26
North Dakota:				
Bismarck	1		1	8
Carrington	1	1		23
Jamestown	1	1		200
Manden	1		1	10
New Rockford	1	1		23
Oklahoma:				
Pauls Valley	1	1		39
Pawhuska	1		1	68
South Dakota:				
Beresford	1	1		16
Ft. Pierre	1	1		16
Huron	1	1		282
Salem	1	1		13
Virginia:				
Ashland	1	1		19
Emporia	1	1		22
South Hill	2	2		10,10
Totals	38	27	11	

SECTION II

ESTIMATES OF CONSTRUCTION AND RELATED COSTS

Estimates of construction and other initial investment costs for wastewater stabilization ponds are presented in this section. These include the construction cost of the pond, and aeration equipment if used; the cost of land for the pond site; engineering costs; legal, fiscal and administrative costs; and interest during construction.

POND CONSTRUCTION COST

Estimates of construction costs have been developed for both aerated and nonaerated stabilization ponds. The great majority of existing ponds are nonaerated, depending solely on algae and wind action to supply the oxygen necessary to oxidize the organic matter. In the past several years there has been an increasing number of aerated stabilization ponds constructed. These ponds characteristically have greater water depth than nonaerated ponds and have mechanical equipment to provide accelerated aeration in all, or a portion of, the pond.

Nonaerated Stabilization Ponds.

Nonaerated stabilization ponds have been used extensively in smaller communities because of the relatively low initial cost, operation and maintenance cost, and manpower requirements, when compared with other types of wastewater treatment facilities. Nonaerated stabilization ponds normally have a liquid depth on the order of 3 to 5 feet. Smaller ponds generally have only one cell while larger size ponds are generally divided into two or more cells, with the influent piping arranged to permit the cells to be operated in parallel, or in series.

Such ponds are most often sized on the basis of organic load per unit of surface area. In this report pond construction costs are related to the total water surface area at the normal operating water depth.

Figure 62, Page 210, shows the plotting of experience construction costs of nonaerated ponds against the respective water surface area of the ponds. The curve shown on Figure 62 represents the estimated average construction costs of nonaerated stabilization ponds of the sizes indicated. The estimated average costs include construction at the pond site for an access road, outfall sewer, fencing, seeding of embankments, and other construction work, with the exception of pumping stations and embankment protection other than seeding. Costs of pumping stations, if required, may be estimated on the basis of data shown in Part One of this report. Data for estimating costs of more extensive embankment protection are provided separately in this section of the report.

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It must be recognized that the costs of constructing a wastewater stabilization pond in any particular location can vary widely from the average cost due to such factors as terrain, soil characteristics, amount of vegetation, length of outfall sewer, and proximity of access road.

Aerated Stabilization Ponds.

The practice of accelerating the aeration process in stabilization ponds through mechanical means permits the use of deeper and much smaller size ponds to treat a given quantity of wastewater than is required for nonaerated ponds.

Construction costs of aerated stabilization ponds shown in this report are based on estimates since experience cost data has not been available for such facilities. Estimates of construction costs for aerated ponds, excluding embankment protection and mechanical aeration equipment, are shown graphically on Figure 63, Page 211. The cost curves shown on Figure 63 are for ponds with 10 and 15 foot water depths.

The estimated average costs shown include construction within the pond site for an access road, outfall sewer, fencing, seeding, and other construction work. Data for estimating the added costs of embankment protection and mechanical aeration equipment are provided for separately.

AERATION EQUIPMENT COST

The construction costs of aeration equipment for wastewater stabilization ponds vary widely, depending upon the type and size of equipment used. The most common types of equipment include surface aerators, mounted on either stationary or floating platforms, and various types of air tubing and diffusion systems. Since the type and cost of equipment to be used is highly dependent upon local conditions, the estimates shown in this report are limited to surface aerators, which have had a wide range of application in recent years.

The costs which may be applicable to the various types of aeration equipment differ, but for surface aerators the horsepower installed is considered the most suitable single parameter. Estimated costs for both large impeller and small impeller aerator installations have been developed. The large impeller aerator has a relatively high mixing capability per motor horsepower compared with the small impeller aerator. Estimates of large impeller installations provide for stationary platforms and walkways. The small impeller installations are estimated on the basis of floating platforms.

Figure 64, Page 212, shows graphically the estimated construction costs in average cost curves for both types of installations. The estimating curves on Figure 64 include allowances for necessary mechanical and electrical equipment including controls, one spare mixer unit, and supporting structures and connecting walkways for stationary platform installations.

EMBANKMENT PROTECTION COSTS

The necessity for extensive erosion protection of embankments forming stabilization ponds varies with the local situation. Seeding of embankments is normal and such costs are included in estimates shown on Figures 62 and 63. The potential for damage of embankments due to wave action are highest in ponds having a large open expanse of water surface subject to wind action. Embankments forming aerated ponds of all sizes are also subject to damage from agitated water.

While embankment protection consisting of dumped rip rap may be suitable in some instances, concrete slab protection is often warranted. Other types of protection, such as various fabrics, also may be considered.

For purposes of this report the estimated costs of concrete slab bank protection as related to the surface area of the pond, have been developed and are shown on Figure 65, Page 213. The average cost estimates provide an allowance for slab surfacing on the interior of the embankment for the full perimeter of the pond cells. The estimator should include these costs in construction cost estimates only to the extent deemed necessary under local circumstances.

CHLORINATION FACILITIES

Chlorination of the effluent from stabilization ponds generally is not required at the present time. This is probably due to the fact that most stabilization ponds are designed and constructed to provide for a detention time of 30 days or more, which normally produces a satisfactory reduction of pathogenic organisms. Because of the fact that the detention time in aerated ponds is usually of a shorter duration, disinfection may be expected to become more common in the future.

The construction costs of chlorination feed systems are related to the average rate of chlorine use at design flow conditions. The capacity range of chlorination equipment is quite large, and the cost of the equipment is relatively unaffected by the rate of chlorine use. The building cost is more directly related to the quantity of chlorine used because of the need to provide space to store chlorine containers between delivery dates.

The estimated costs to construct chlorination feed systems are related to average rate of chlorine use, and are shown on Figure 66, Page 214. Cost estimates shown are similar to those on Figure 10, Page 43 , in Part One. Experience data in the range required for waste stabilization ponds are limited. As a supplement to the limited experience cost data, estimates of construction costs of other chlorination installations have been prepared and are also shown on Figure 66. The estimated cost data have been developed and used principally as a means of extending the data range to the smaller sizes of installations required. The curve shown on Figure 66 reflects the cost of equipment and a building adequate in size to provide space for the installation of chlorine feed and accessory equipment, and to provide space to store an adequate number of chlorine containers.

For chlorination to be effective as a disinfectant, a contact time of 30 minutes at the design average day flow rate or 15 minutes at the maximum flow rate, whichever requirement is greater, is commonly allowed at wastewater treatment facilities. Unless the outfall sewer from the pond is of a length adequate to provide a proper chlorine contact period, a contact basin is required. Figure 67, Page 215, shows experience costs of 6 contact basin installations and costs of 3 estimated basins, plotted against the respective liquid volumes of the basins. Estimated data points are used solely as a guide to the shape of the curve and its extension beyond the limits of experience data. Estimates of average contact basin construction costs are represented by the curve shown on Figure 67 and include allowances for costs of the basin structure, normal excavation, baffles to prevent short circuiting of flow through the basin, valves, and bypass piping.

ENGINEERING

Engineering for wastewater stabilization pond projects consists of the two elements of basic services and special services. Basic services include preliminary design reports, detailed design, and certain office and field engineering services during construction of projects. Special services include comprehensive improvement studies, resident engineering, soils investigations, land surveys, preparation of applications for government grants, operation and maintenance manuals, and other miscellaneous services.

The American Society of Civil Engineers (ASCE) has published curves, designated A and B, showing median compensation for basic engineering services of varying complexity. These curves are periodically reviewed and are subject to revision from time to time. The ASCE curves have been used in developing estimates of basic engineering services costs.

Average costs of special engineering services are included with costs of basic services in the estimates of total engineering costs indicated by the total cost curve on Figure 68, Page 216.

LAND REQUIREMENTS AND COSTS

The amount of land required for construction of wastewater stabilization ponds varies with a number of factors including water surface area, pond depth, terrain, possible allowances for expansion, and whether the area is open or wooded. The area of land actually purchased may also be influenced by the size of tracts available at the selected location.

Figure 69, Page 217, shows the estimated land requirements for average stabilization ponds related to water surface area. No allowance is included for irregular terrain or future expansion. Since land costs may vary from a few hundred dollars per acre in essentially rural areas to over one thousand dollars per acre in urban areas, average land costs have not been estimated.

LEGAL, FISCAL AND ADMINISTRATIVE COSTS

Costs of legal and fiscal services, and of owner administration related to planning and construction of wastewater stabilization pond facilities can be substantial. Legal documents must be prepared and the legality of bonds must be certified by qualified bond attorneys. The costs of legal and fiscal consulting services are related to some degree to the total amount of debt financing, and hence to total construction, engineering, and land costs. Legal assistance may also be required in other areas such as the preparation of construction contracts, and in the acquisition of land.

Even though consultants are used, the administration of the financing, design, and construction of wastewater treatment plants may require substantial time on the part of owner personnel. These items of cost may also be related to the project size as indicated by the total cost.

Total costs of legal, fiscal, and administrative services may be expected to vary widely from one situation to another. Average costs may range from about 5 per cent of the costs of small projects to about 1 per cent of the costs of larger projects. Figure 70, Page 218, shows estimated average legal, fiscal and administrative costs related to total construction, engineering, and land costs.

INTEREST DURING CONSTRUCTION

As used herein, interest during construction is the interest cost accrued on funds from the time that payment is made to the contractor until the end of the construction period. Interest during construction is a real cost, whether a project is financed through the issuance of debt securities, from accrued earnings, or from other sources. It may be assumed that the interest rate paid on borrowed funds is a valid measure of this cost.

Municipalities frequently finance the construction of wastewater treatment projects from the sale of bonds prior to construction. Bond funds are normally invested in short term securities until needed for payments to the contractor, with short term interest income acting as an offset to long term interest expense. Hence, the net expense for interest during construction may not begin until the actual payment is made to the contractor.

The owner's cost of interest during construction depends upon current interest rates, the length of the construction period, the pattern of payments to the contractor, and the total project costs.

An analysis of monthly payments to contractors for a number of projects indicates that, while there is considerable variation in the size of monthly payments, the average period over which interest is accrued amounts to approximately one-half the total construction period. Similarly, the total construction period varies with the construction cost, and is estimated to be as shown in the following tabulation.

Total Construction Cost	Estimated Total Construction Period
	months
30,000	2
40,000	2
60,000	3
80,000	3
100,000	4
500,000	8
1,000,000	10
2,000,000	12

The estimated average cost of interest during construction is related to total other project costs on Figure 71, Page 219, for annual rates of interest of 4, 6, and 8 per cent, respectively. Cost estimates are based upon construction periods shown and an average period of interest equal to one-half the construction period. The estimated interest costs may range from a lower limit of about 0.5 per cent of small project costs to about 5 per cent of the costs of large projects.

APPLICATION OF INITIAL INVESTMENT COST ESTIMATING DATA

Table 17, Page 208, presents a form prepared for the purpose of estimating initial investment costs for wastewater stabilization pond projects. It is assumed that the estimator will have determined from preliminary design the required size of the cost component parameters. Based upon this premise, the total initial investment cost may be estimated.

Table 17-A, Page 209, illustrates the use of the estimated construction cost data developed in this part of the report for estimating the total initial investment cost for a wastewater stabilization pond. The example is based upon a hypothetical nonaerated stabilization pond with an average design capacity of 1.0 million gallons per day which, in this instance, is assumed to require a water surface area of 57 acres.

The sizes of individual cost components shown for the example are representative of average conditions which may be encountered for the assumed facility. However, since variations in the sizes of respective components may be significant, due to differences in local conditions, the total cost indicated in the example cannot be considered representative for any particular 1.0 mgd installation.

The limitations of cost estimates based upon average conditions is again emphasized. Construction cost data presented herein are applicable as a basis of preliminary estimates for planning requirements and methods, and for general comparative studies of costs. These data, unadjusted for particular local conditions, should not be used for cost estimates in specific locations. This cost estimate source does not supplant the need for individual engineering studies of project costs.

TABLE 17

ESTIMATED INITIAL INVESTMENT COST

Project ____________________; Computed By ____________; Date _________

Cost Component	Component Parameter	Cost Estimate Reference Figure No.	Cost Estimate Cost $
Pond Construction:			
Nonaerated Pond	_____ acres water surface area	62	________
Aerated Pond			
Water depth of 10 feet	_____ acres water surface area	63	________
Water depth of 15 feet	_____ acres water surface area	63	________
Aeration Equipment			
Large Impeller	_____ horsepower total installed capacity	64	________
Small Impeller	_____ horsepower total installed capacity	64	________
Embankment Protection	_____ acres water surface area	65	________
Chlorination - Feed System	_____ pounds per day average chlorine use at design flow	66	________
Chlorination - Contact Basin	_____ 1000 cubic feet liquid volume	67	________
____________________	____________________	___	________
____________________	____________________	___	________
____________________	____________________	___	________
____________________	____________________	___	________
____________________	____________________	___	________
Total Estimated Construction Cost at January, 1971 Cost Level		Total	________
Trended Total Estimated Construction Cost	________% Trend Factor (See note below)	Total	________
Engineering		68	________
Land	_____ acres at $_________ per acre	69	________
Subtotal-Construction, Engineering & Land		Subtotal	________
Legal, Fiscal, & Administrative		70	________
Subtotal All Above		Subtotal	________
Interest During Construction	(At _____% interest)	71	________
Total Initial Investment Cost		Total	________

Note:

$$\text{Trend Factor} = \frac{\text{Local WQO-STP Cost Index representative of the construction period}}{\text{National Average WQO-STP Cost Index as of January 1, 1971}} = \frac{\_\_\_\_\_}{150.60} = \_\_\_\_\_\%$$

TABLE 17-A

ESTIMATED INITIAL INVESTMENT COST

Project *Highville, Kansas* ; Computed By *RWB* ; Date *Sept 1971*

Cost Component	Component Parameter	Cost Estimate Reference Figure No.	Cost Estimate Cost $
Pond Construction:			
Nonaerated Pond	*57* acres water surface area	62	*270,000*
Aerated Pond			
Water depth of 10 feet	____ acres water surface area	63	
Water depth of 15 feet	____ acres water surface area	63	
Aeration Equipment			
Large Impeller	____ horsepower total installed capacity	64	
Small Impeller	____ horsepower total installed capacity	64	
Embankment Protection	*57* acres water surface area	65	*35,000*(a)
Chlorination - Feed System	____ pounds per day average chlorine use at design flow	66	
Chlorination - Contact Basin	____ 1000 cubic feet liquid volume	67	
Total Estimated Construction Cost at January, 1971 Cost Level		Total	*305,000*
Trended Total Estimated Construction Cost	*122.1* % Trend Factor (See note below)	Total	*372,000*
Engineering		68	*44,000*
Land	*76* acres at $ *500* per acre	69	*38,000*
Subtotal-Construction, Engineering & Land		Subtotal	*454,000*
Legal, Fiscal, & Administrative		70	*9,000*
Subtotal All Above		Subtotal	*463,000*
Interest During Construction	(At *6* % interest)	71	*9,000*
Total Initial Investment Cost		Total	*472,000*

Note:

$$\text{Trend Factor} = \frac{\text{Local WQO-STP Cost Index representative of the construction period}}{\text{National Average WQO-STP Cost Index as of January 1 1971}} = \frac{183.9}{150.60} = 122.1\%$$

(a) *Estimate one-half of dike perimeter needs protection*

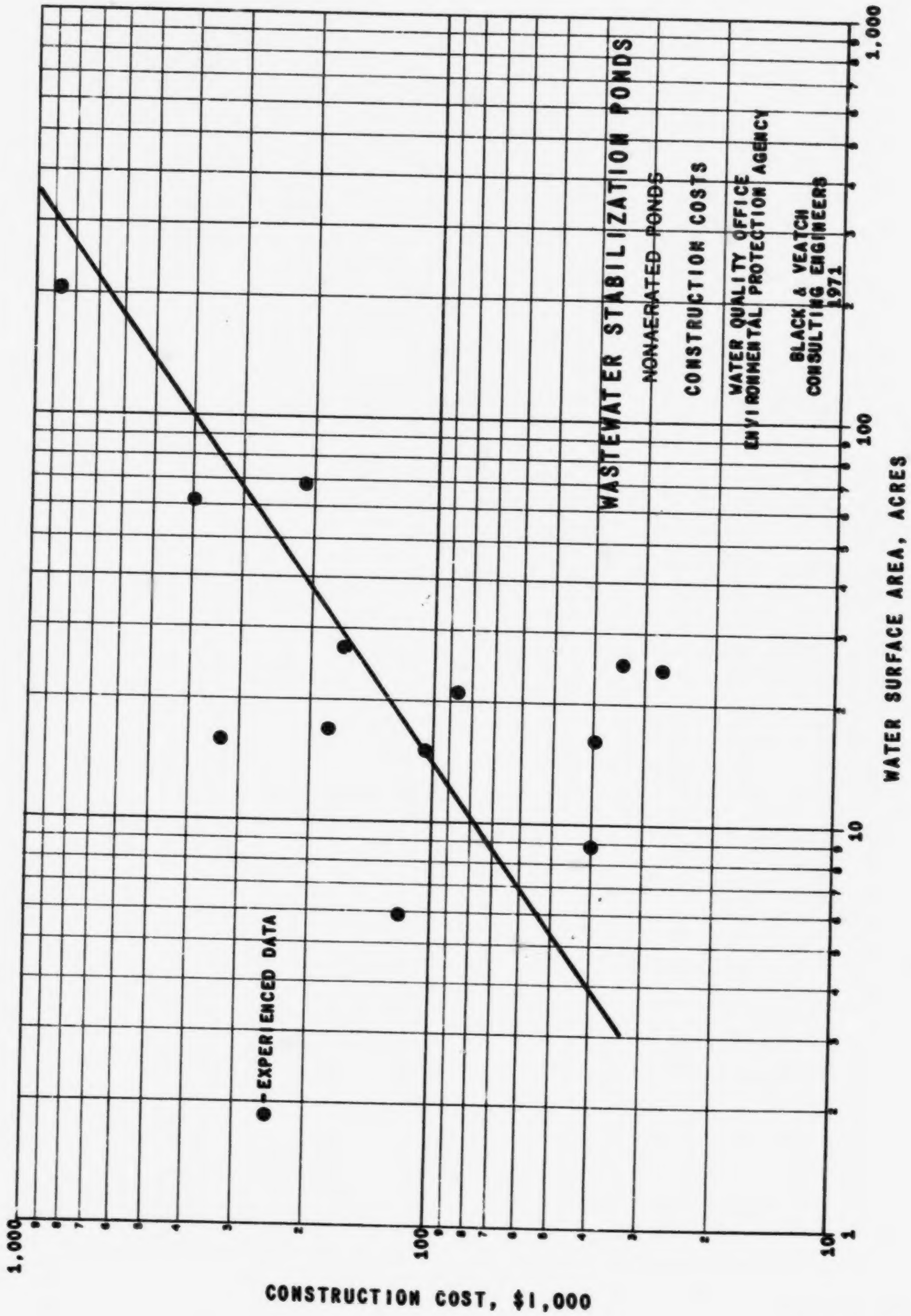

WASTEWATER STABILIZATION PONDS
NONAERATED PONDS
CONSTRUCTION COSTS
WATER QUALITY OFFICE
ENVIRONMENTAL PROTECTION AGENCY
BLACK & VEATCH
CONSULTING ENGINEERS
1971
● - EXPERIENCED DATA
WATER SURFACE AREA, ACRES
1
10
100
1,000
CONSTRUCTION COST, $1,000
10
100
1,000

FIGURE 62

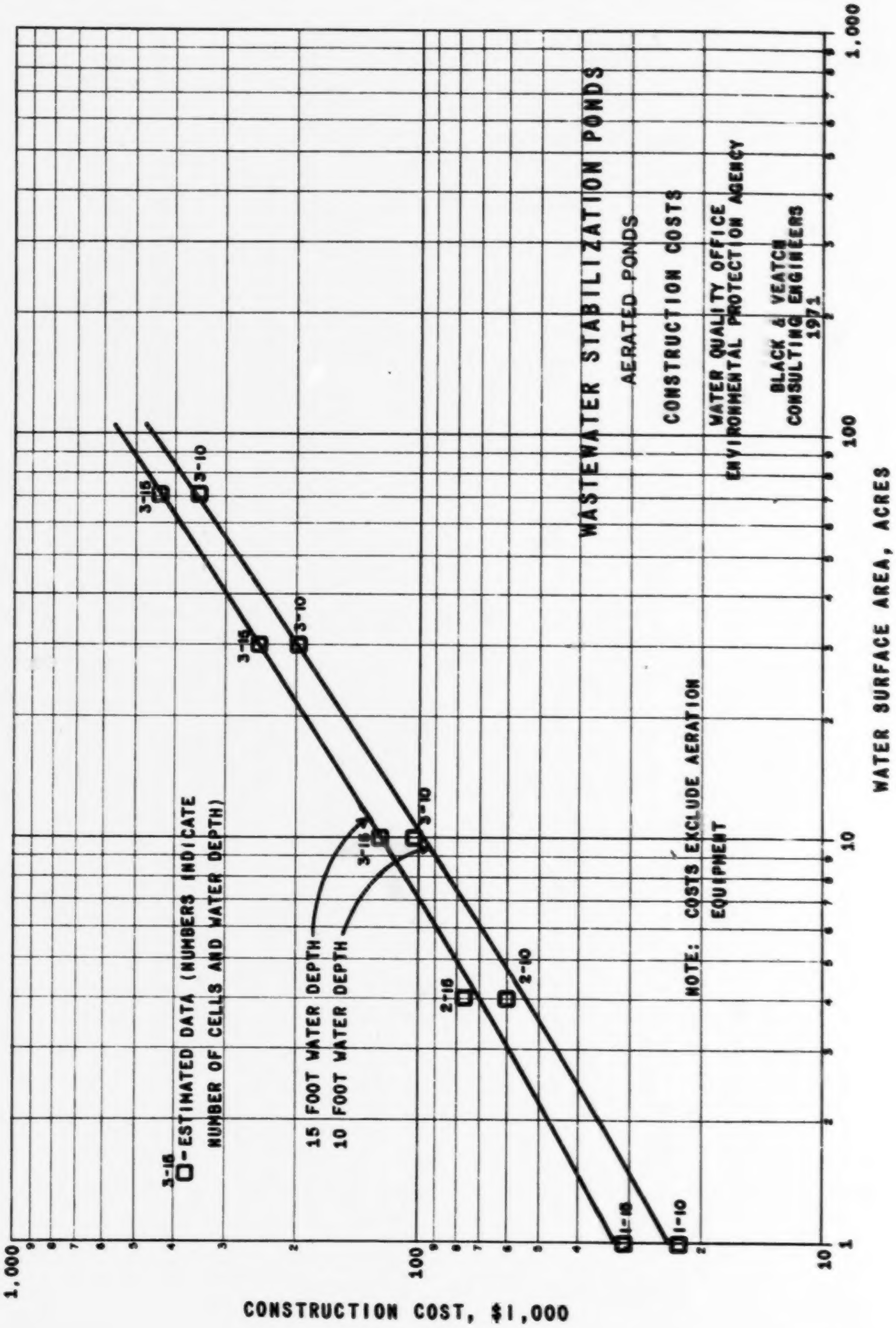

WASTEWATER STABILIZATION PONDS
AERATED PONDS
CONSTRUCTION COSTS
WATER QUALITY OFFICE
ENVIRONMENTAL PROTECTION AGENCY
BLACK & VEATCH
CONSULTING ENGINEERS
1971
□ - ESTIMATED DATA (NUMBERS INDICATE NUMBER OF CELLS AND WATER DEPTH)
3-15
15 FOOT WATER DEPTH
10 FOOT WATER DEPTH
NOTE: COSTS EXCLUDE AERATION EQUIPMENT
1-15
1-10
2-15
2-10
3-15
3-10
3-15
3-10
3-15
3-10
CONSTRUCTION COST, $1,000
10
100
1,000
WATER SURFACE AREA, ACRES
1
10
100
1,000

FIGURE 63

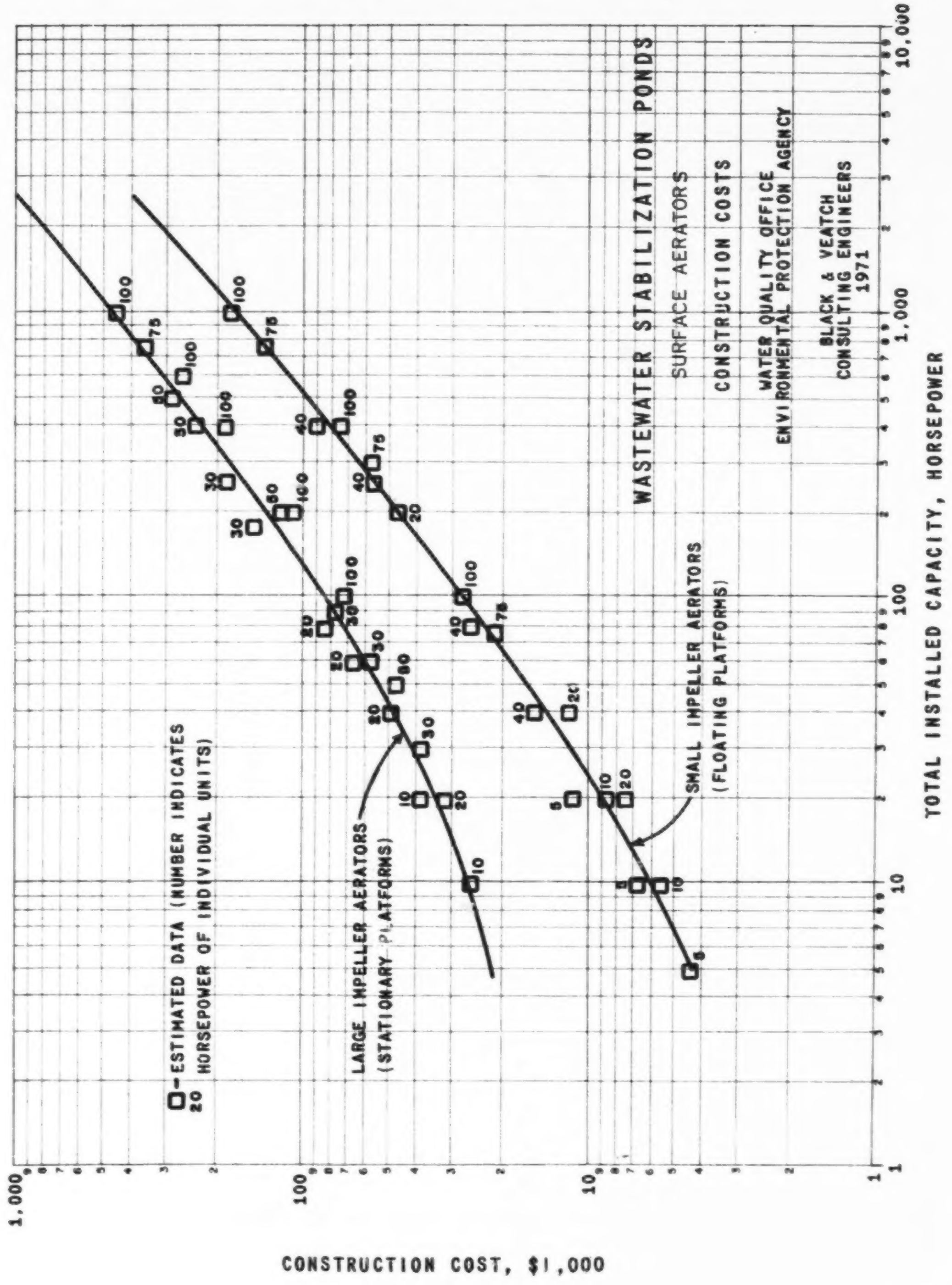
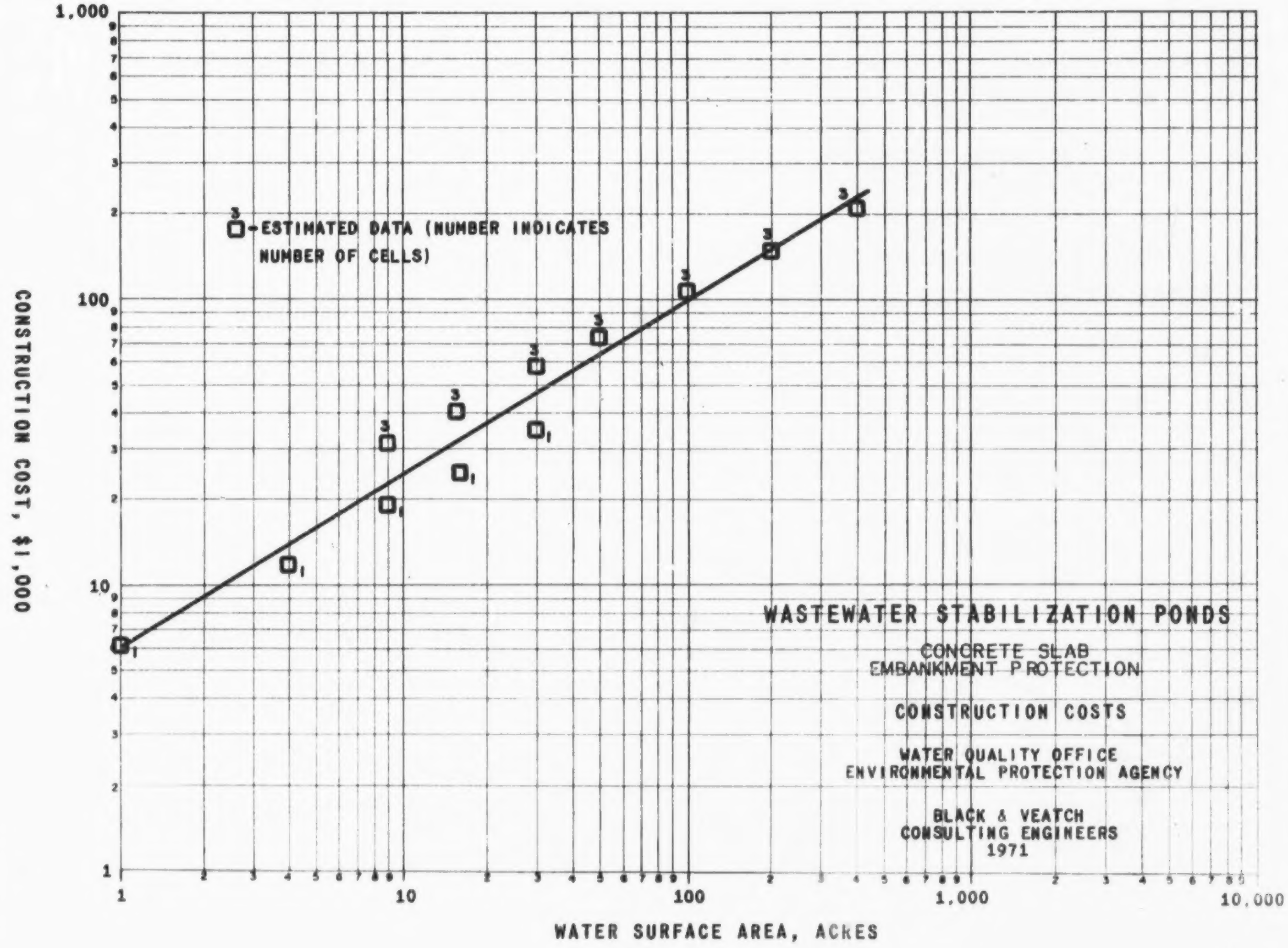

WASTEWATER STABILIZATION PONDS
SURFACE AERATORS
CONSTRUCTION COSTS
WATER QUALITY OFFICE
ENVIRONMENTAL PROTECTION AGENCY
BLACK & VEATCH
CONSULTING ENGINEERS
1971
□ - ESTIMATED DATA (NUMBER INDICATES HORSEPOWER OF INDIVIDUAL UNITS)
20
LARGE IMPELLER AERATORS (STATIONARY PLATFORMS)
SMALL IMPELLER AERATORS (FLOATING PLATFORMS)
TOTAL INSTALLED CAPACITY, HORSEPOWER
1
10
100
1,000
10,000
CONSTRUCTION COST, $1,000
1
10
100
1,000

FIGURE 64



3 □ → ESTIMATED DATA (NUMBER INDICATES NUMBER OF CELLS)
WASTEWATER STABILIZATION PONDS
CONCRETE SLAB
EMBANKMENT PROTECTION
CONSTRUCTION COSTS
WATER QUALITY OFFICE
ENVIRONMENTAL PROTECTION AGENCY
BLACK & VEATCH
CONSULTING ENGINEERS
1971
CONSTRUCTION COST, $1,000
1,000
100
10
1
WATER SURFACE AREA, ACRES
1
10
100
1,000
10,000

FIGURE 65

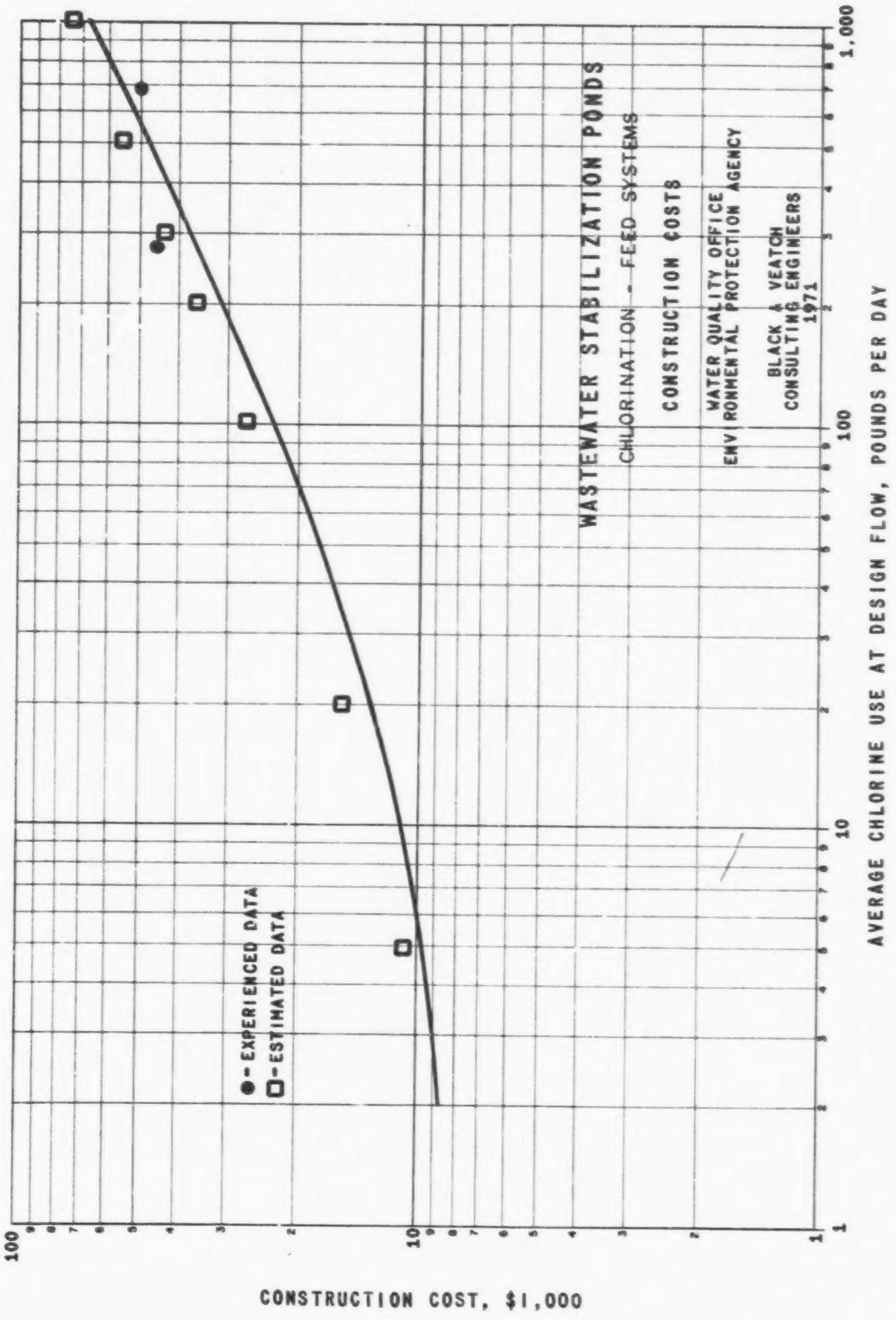

WASTEWATER STABILIZATION PONDS
CHLORINATION - FEED SYSTEMS
CONSTRUCTION COSTS
WATER QUALITY OFFICE
ENVIRONMENTAL PROTECTION AGENCY
BLACK & VEATCH
CONSULTING ENGINEERS
1971
● - EXPERIENCED DATA
□ - ESTIMATED DATA
AVERAGE CHLORINE USE AT DESIGN FLOW, POUNDS PER DAY
1
10
100
1,000
CONSTRUCTION COST, $1,000
1
10
100

FIGURE 66

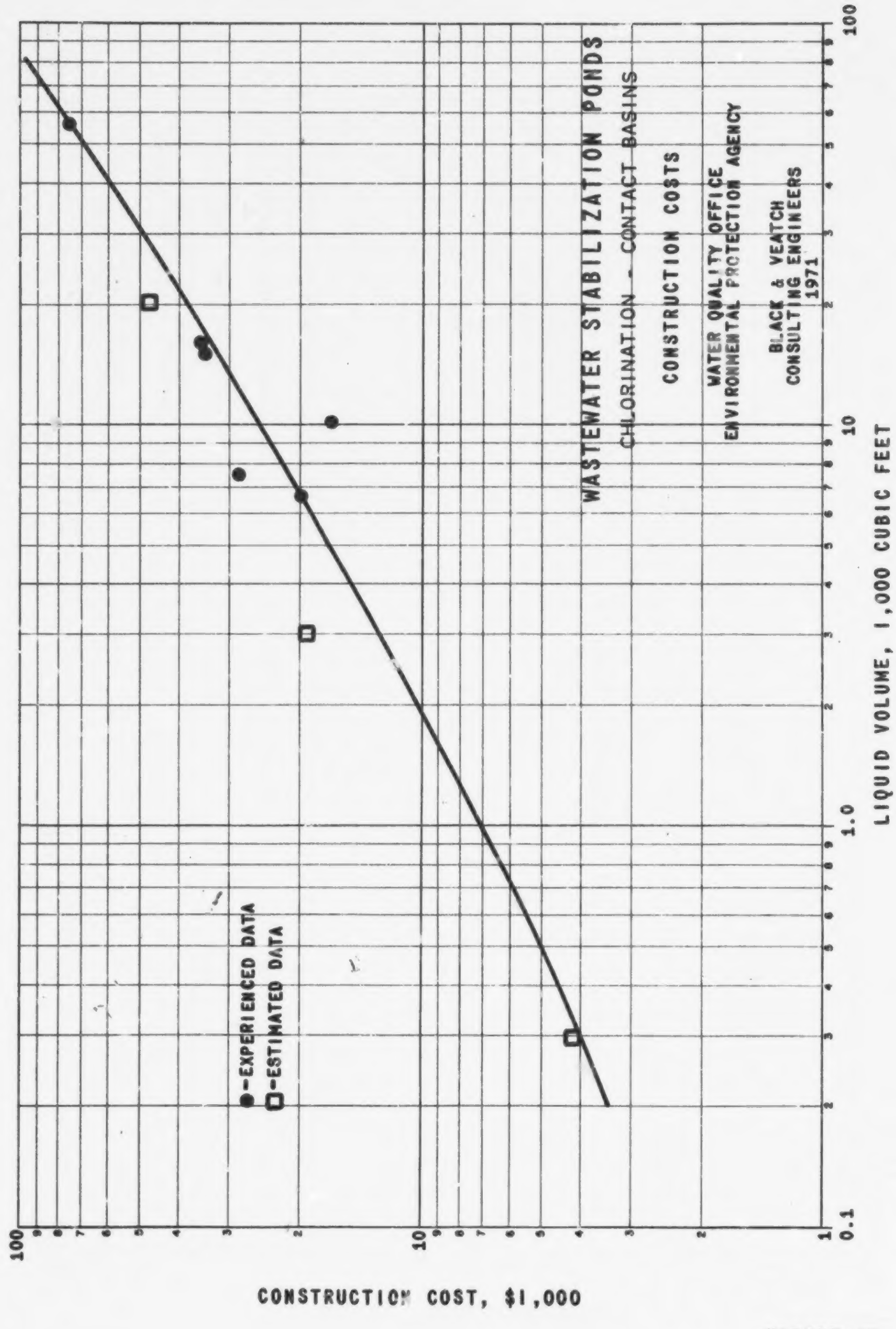

WASTEWATER STABILIZATION PONDS
CHLORINATION - CONTACT BASINS
CONSTRUCTION COSTS
WATER QUALITY OFFICE
ENVIRONMENTAL PROTECTION AGENCY
BLACK & VEATCH
CONSULTING ENGINEERS
1971
● -EXPERIENCED DATA
□ -ESTIMATED DATA
LIQUID VOLUME, 1,000 CUBIC FEET
0.1
1.0
10
100
CONSTRUCTION COST, $1,000
1
10
100

FIGURE 67

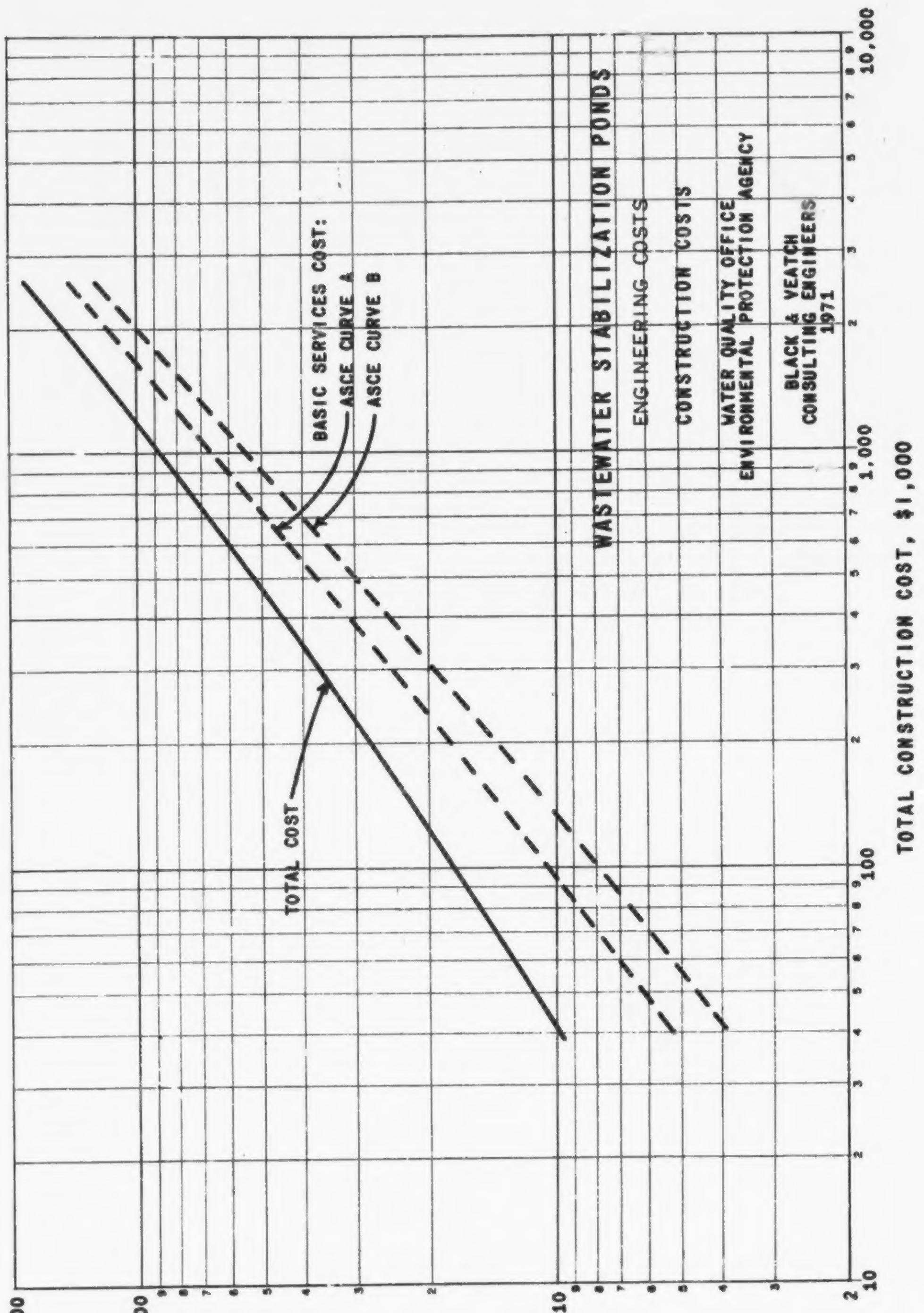
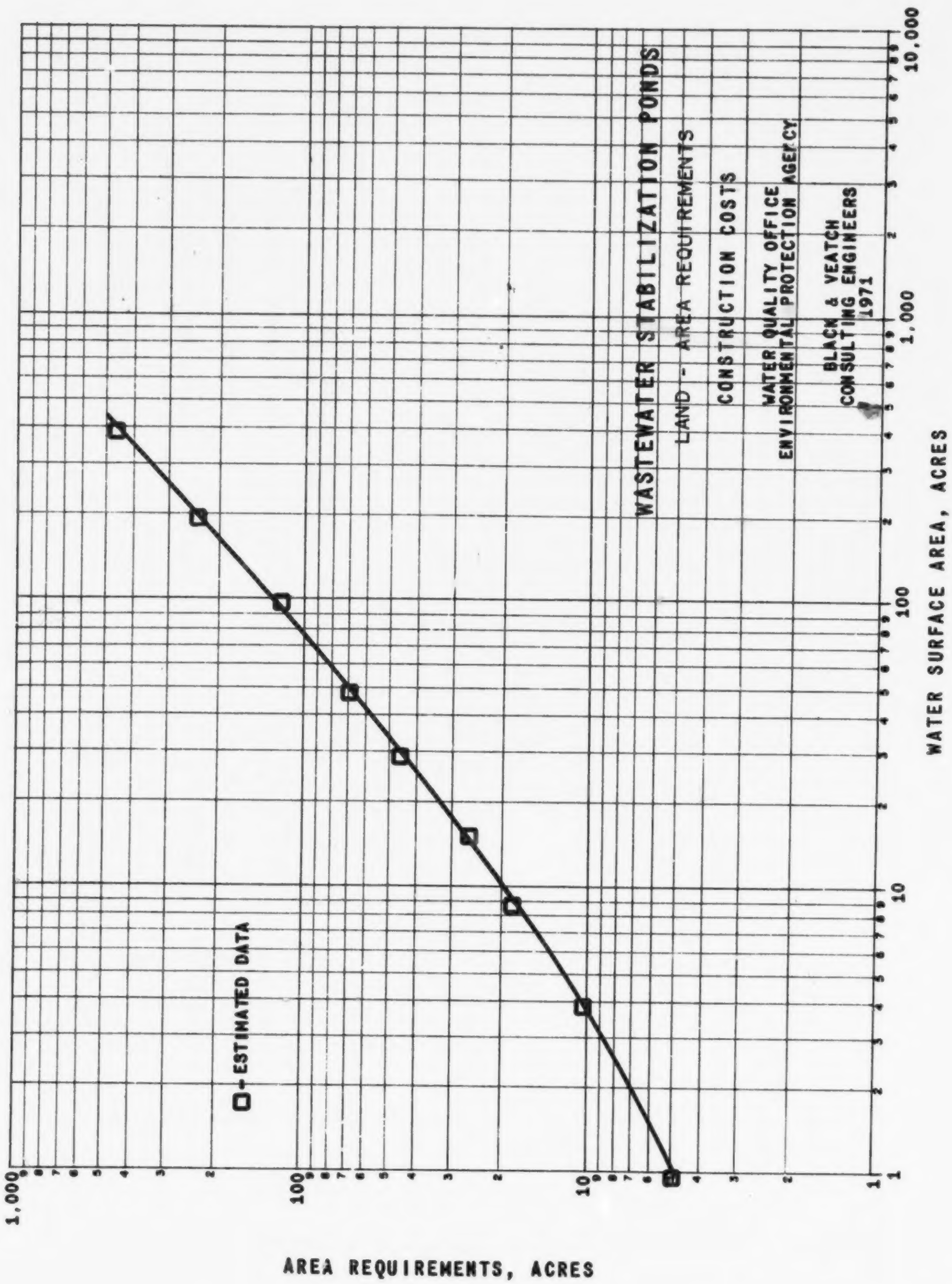

WASTEWATER STABILIZATION PONDS
ENGINEERING COSTS
CONSTRUCTION COSTS
WATER QUALITY OFFICE
ENVIRONMENTAL PROTECTION AGENCY
BLACK & VEATCH
CONSULTING ENGINEERS
1971
BASIC SERVICES COST:
ASCE CURVE A
ASCE CURVE B
TOTAL COST
TOTAL CONSTRUCTION COST, $1,000
10
100
1,000
10,000
ENGINEERING COST, $1,000
2
10
100
200

FIGURE 68



WASTEWATER STABILIZATION PONDS

LAND - AREA REQUIREMENTS

CONSTRUCTION COSTS

WATER QUALITY OFFICE
ENVIRONMENTAL PROTECTION AGENCY

BLACK & VEATCH
CONSULTING ENGINEERS
1971

FIGURE 69

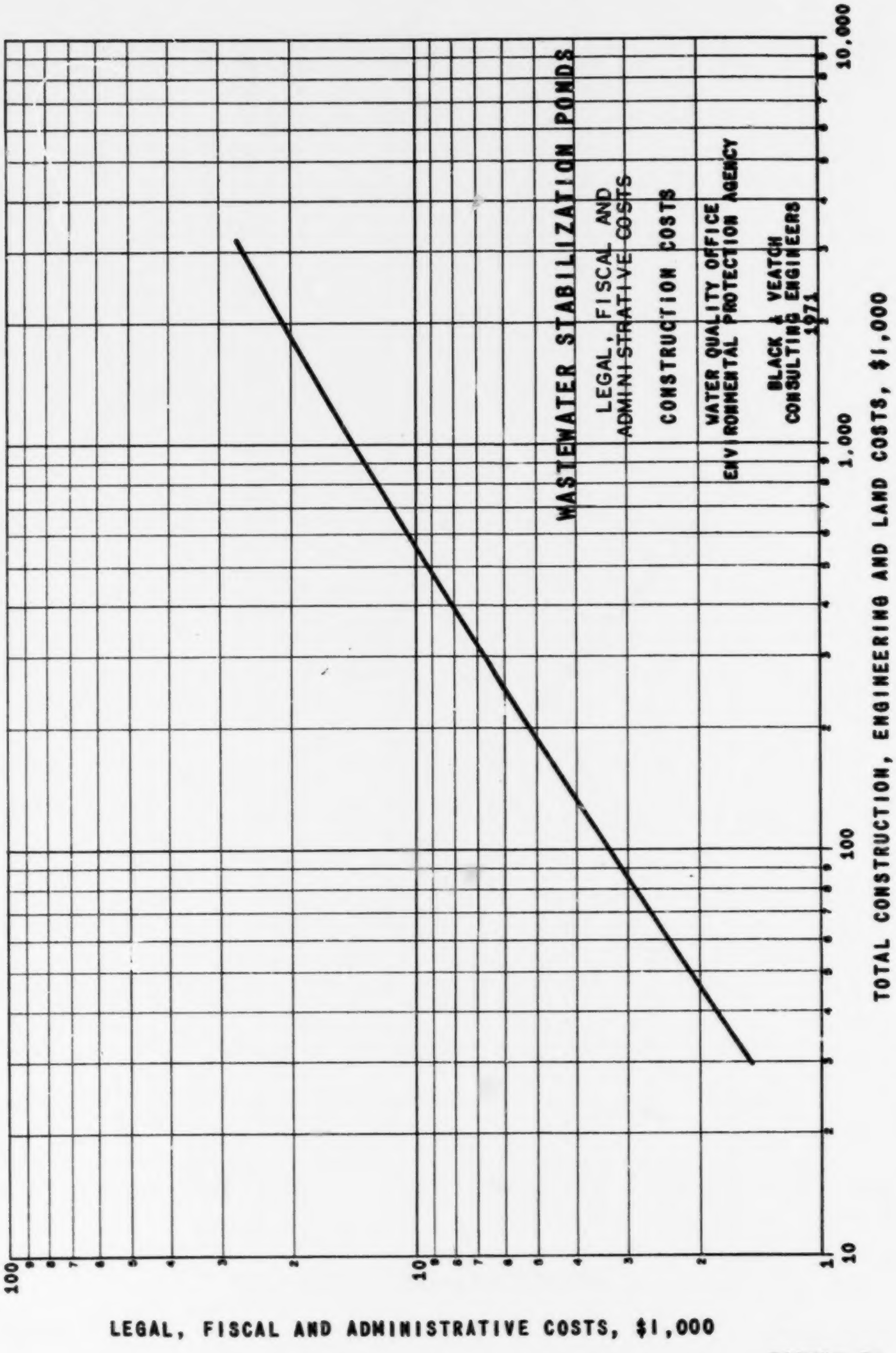

WASTEWATER STABILIZATION PONDS
LEGAL, FISCAL AND ADMINISTRATIVE COSTS
CONSTRUCTION COSTS
WATER QUALITY OFFICE
ENVIRONMENTAL PROTECTION AGENCY
BLACK & VEATCH
CONSULTING ENGINEERS
1971
TOTAL CONSTRUCTION, ENGINEERING AND LAND COSTS, $1,000
10
100
1,000
10,000
100
10
1
LEGAL, FISCAL AND ADMINISTRATIVE COSTS, $1,000

FIGURE 70

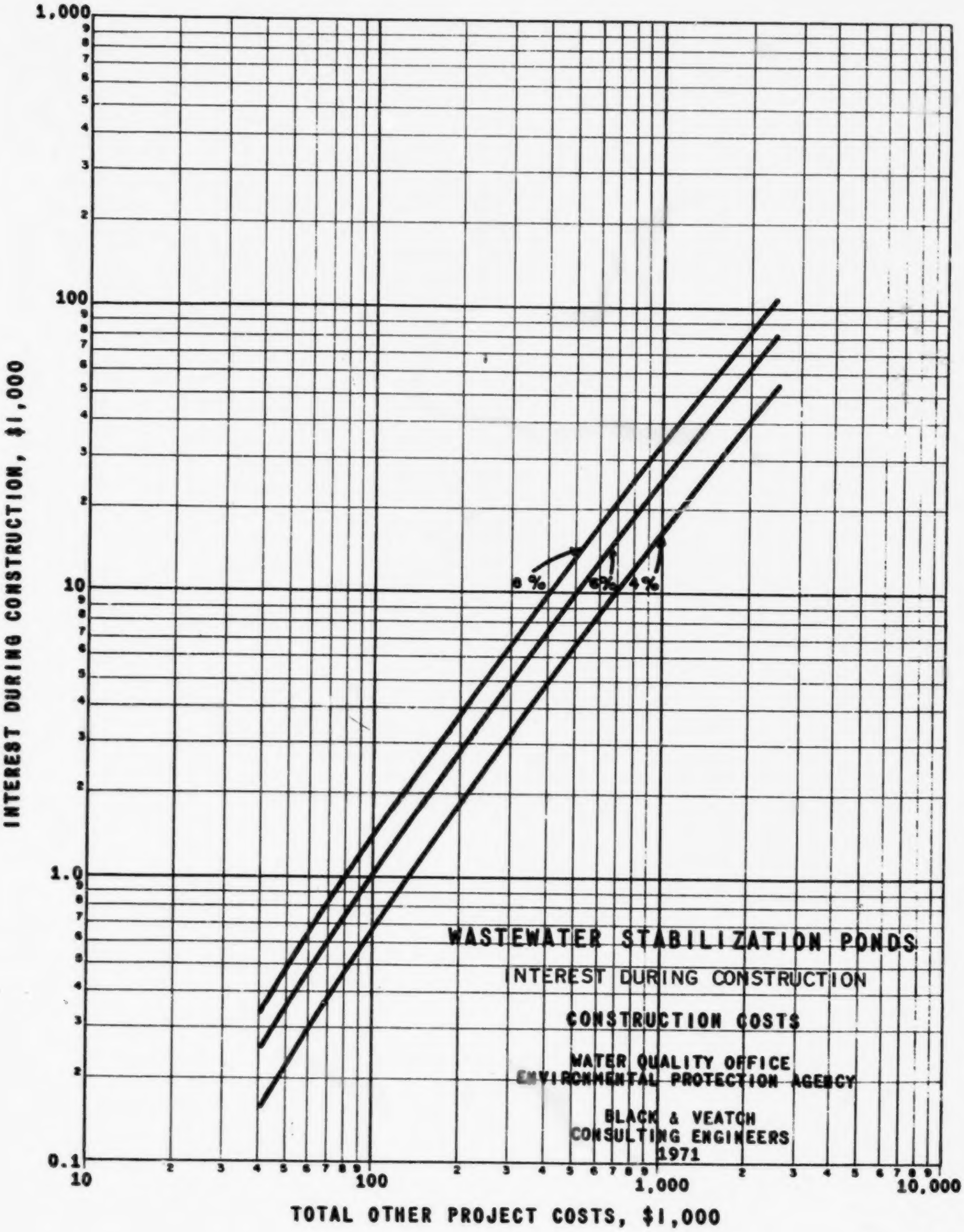

1,000
100
10
1.0
0.1
10
100
1,000
10,000
INTEREST DURING CONSTRUCTION, $1,000
TOTAL OTHER PROJECT COSTS, $1,000
8%
6%
4%
WASTEWATER STABILIZATION PONDS
INTEREST DURING CONSTRUCTION
CONSTRUCTION COSTS
WATER QUALITY OFFICE
ENVIRONMENTAL PROTECTION AGENCY
BLACK & VEATCH
CONSULTING ENGINEERS
1971

FIGURE 71

SECTION III

ESTIMATES OF OPERATION AND MAINTENANCE COSTS

This section of the report develops means of estimating operation and maintenance costs of principal components of wastewater stabilization ponds. Major elements of cost considered include payroll man-hours for both operation and maintenance, and cost of material and supplies. Each of the major cost elements is expressed in relation to appropriate sizing parameters for each of the principal pond components.

Estimates of total operating expenses may be developed on the basis of the average cost information presented. The cost estimating data are considered appropriate for stabilization ponds built in recent years which are in sound structural and operating condition. The data are intended to reflect average operating conditions and procedures.

Estimates of operation and maintenance costs are based principally on information obtained from field investigation of 38 actual operating wastewater stabilization ponds located in 27 communities. The geographic locations and types of ponds investigated for which data were collected are listed in Table 16, Page 199. Cost elements have been estimated where field information was not available or insufficient.

Data obtained during the field investigations included the pond size and construction features, condition of the pond, operation and maintenance requirements of the pond during the various seasons of the year, manpower used to operate and maintain the pond, direct and indirect labor costs associated with pond operation, and laboratory test data when it was available. The relationships of operation and maintenance cost components to appropriate parameters are based upon graphical analysis of experience data when such data was available. It should be realized that it is not possible to recognize all variations in operation and maintenance practices occurring among individual stabilization ponds. Therefore, judgment has been exercised by the investigators in the establishment of curves designating cost relationships. The resulting curves represent the investigators' judgment as to average cost data.

Based upon variations in experienced operating cost data, it may be expected that actual data for individual stabilization ponds will vary widely, often 100 per cent or more, from the average represented by the curves. These variations can result from such factors as differences in pond design, operating procedures, and flexibility in the use of personnel. While actual costs may vary appreciably from the estimated averages, data presented should be of value, when used with judgment, as basic indicators for preliminary cost estimates.

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The user should recognize the inherent limitations of such estimates and should base operating cost estimates on more detailed study to the extent warranted by local circumstances.

Data for estimating operation and maintenance cost of each of the cost components of wastewater stabilization ponds include annual payroll man-hours for operation, maintenance, and administrative and general labor, and annual cost of material and supplies. A basis is provided for estimating indirect labor costs such as social security; contributions to pension, retirement or welfare funds; and premiums paid for hospitalization, health, life and workmen's compensation insurance which may be incurred by the owner of the pond.

Following the presentation of cost relationships for the various cost components of wastewater stabilization ponds, a calculation summary form and example application are presented as illustrations of their use.

LABOR REQUIREMENTS

To permit adaptation of estimating data to local conditions, operation and maintenance labor requirements are presented in the form of payroll man-hours required related to appropriate capacity or use parameters, rather than direct dollar cost. This will permit application of current local labor rates to estimated man-hour requirements in developing labor cost estimates for any particular local situation.

The annual payroll man-hours for operation and maintenance, respectively, are indicative of the total requirement for personnel to adequately operate and maintain the facility. Man-hour requirements are based on a normal payroll year consisting of 52 weeks at 40 hours per week, or a total of 2,080 hours per year. Effective working time is estimated to be 90 per cent of the payroll man-hours, with the remaining 10 per cent representing paid vacations, holidays, sick time and other paid time away from the job.

The estimates of labor requirements for operation and maintenance of stabilization ponds reflect the use of employees on a part-time basis where the time of employees devoting full efforts to this work cannot be effectively utilized. It must be recognized that the estimates of payroll man-hours shown are only representative of requirements. They are a valid basis for estimating the labor costs only if the man-hours required can be obtained efficiently, with any balance of an employee's time available to be used effectively elsewhere.

Nonaerated Stabilization Ponds.

The estimated annual man-hour requirements to operate nonaerated stabilization ponds are shown on Figure 72, Page 230. Annual operating labor estimates include allowances for the time required for inspection of the physical facilities, including embankments, fence and gate, and outfall sewer. Other operating tasks include adjustment of the division of influent flow and of the level of water in the various cells. Operating labor estimates also include allowances for maintaining operating records, collecting wastewater samples, and making necessary qualitative analyses.

The frequency of inspection of physical facilities can cause a significant variation in total annual operating man-hours required. In the warmer climates of the Unites States the necessity of watching closely for development of objectionable algal blooms requires more frequent pond inspections. Figure 72 shows two curves for estimating operating labor payroll man-hours in relation to the water surface area of the pond. One curve is for localities having warm climates where conditions are favorable for algal blooms. The second curve is for localities having cooler climates where algal blooms are not expected.

The estimated annual man-hour requirements to maintain nonaerated ponds are shown on Figure 73, Page 231. The annual maintenance labor requirements associated with a properly operated nonaerated stabilization pond vary not only with the size of the pond but also with the climate at the pond location. Maintenance work required to achieve the maximum efficiency and life of a stabilization pond includes mowing of grass on the pond site; dispersal of floating algae mats; removal of floating scum, grease, and debris; removal of submerged vegetative growth; insect control; and maintenance of dikes, fences, structures, and roads. In warmer climates having longer growing seasons, grass cutting is required more frequently during the year than in areas having shorter growing seasons. A more significant element of cost is the frequency with which floating algae mats, resulting from algal blooms, must be dispersed. In some locations, where the floating algae mat covers a large area of the pond, boats with outboard motors are used to agitate the water and break up the mat, thereby releasing the entrained gases and permitting the algae to settle to the bottom of the pond.

Figure 73, Page 231, shows two curves for estimating the annual man-hour requirements for maintenance labor related to the water surface area. One curve is designated as appropriate for areas having warm climates and the other is for areas having cooler climates.

Aerated Stabilization Ponds.

Estimates of the annual labor required to properly operate and maintain aerated stabilization ponds are shown on Figure 74, Page 232. The annual labor requirements associated with an aerated stabilization pond reflect the need to maintain a close surveillance of the pond operation, including aeration equipment.

The requirements for operating labor are similar to those of nonaerated ponds except for increased frequency of inspection due to the operation of mechanical equipment. Maintenance labor requirements for aerated ponds do not have to deal with algae problems as in nonaerated lagoons, but mechanical aerator equipment must be cared for. The operation and maintenance labor curves shown on Figure 74 reflect these added responsibilities.

Chlorination.

Operating labor for chlorination facilities provides for regular checks on the rate of chlorine use and adjustments of the feed rate when required. As larger quantities of chlorine are used, the need for periodic checks becomes more important to avoid undue costs resulting from excess feed rates and to assure adequate feed. Operating labor also replaces empty chlorine tanks. Maintenance labor repairs and maintains all chlorine handling equipment and contact basins, and provides related maintenance work.

Figure 75, Page 233, shows the estimated annual operation and maintenance labor requirements for chlorination systems related to chlorine use.

Administration and General.

The annual payroll man-hour requirements for administration and general personnel, including necessary superintendence and clerical efforts, are estimated to total 10 per cent of the total other operation and maintenance man-hour requirements. The time required to perform these duties is minimal and personnel assigned would logically occupy some other administration position of a public works nature, depending on the size of the community where the pond is located.

INDIRECT LABOR COSTS

The total annual labor cost of a wastewater utility consists of both direct and indirect labor costs. The direct labor costs include the salaries, wages, and other compensation actually earned by the employees. Examples of direct labor costs include base salaries or wages, overtime and premium pay, and cost of living adjustments. The base salaries or wages applicable to payroll man-hours include pay for nonworked periods such as vacation, sick leave, holidays, excused leave, and injury leave.

Indirect labor costs include those labor-related costs paid by the utility other than salaries, wages and other direct compensation. Examples of indirect labor costs include social security; contributions to pension, retirement, or welfare funds; and premiums paid on hospitalization, health, life, and workmen's compensation insurance.

Wastewater utility labor cost data from 40 cities or sanitary districts have been analyzed to determine the relationship of indirect to direct labor costs. The data analyzed included costs from plants located in 18 states and reflect costs experienced during 1967, 1968, and 1969. The indirect labor costs, expressed as a percentage of the direct labor costs, were generally in the 5 to 20 per cent range and averaged 13.5 per cent. It is suggested that indirect labor costs be estimated at 15 per cent of direct labor costs unless particular knowledge of a local situation indicates a more appropriate figure.

MATERIAL AND SUPPLY COSTS

Material and supply costs for wastewater stabilization ponds include power, fuel, chemicals, gravel, repair parts and equipment rental require for proper operation and maintenance of the facilities. Annual dollars required are presented as a direct relationship to respective parameters, based upon average conditions and on cost levels as of January 1971. To reflect changes in these costs in later periods, they may be trended to the date of the estimate by using figures available in "Wholesale Prices and Price Indexes" published by the Bureau of Labor Statistics, U. S. Department of Labor. The indexes for recent months are shown in this publication in the table entitled "Wholesale Prices Indexes for Major Commodity Groups", under the heading "Industrial Commodities". The index for January 1971 is 112.2. If knowledge of the specific local situation indicates a more appropriate trend, such information should be utilized.

The estimated annual material and supply costs, related to the water surface area of the pond, appropriate for nonaerated stabilization ponds are shown on Figure 76, Page 234. Two cost curves are shown on Figure 76 to indicate the magnitude of these costs depending upon the climatological conditions of the pond location. These curves do not include the cost of chlorine which is estimated separately below.

The estimated annual material and supply costs associated with the operation and maintenance of aerated stabilization ponds are presented on Figure 77, Page 235. The annual material and supply costs estimated for aerated stabilization ponds are divided into two elements, electric power cost and other material and supply costs. Both are related to total horsepower of equipment installed in the pond. Electric power cost estimates are based on average unit power costs of 2.0 cents per kWh at 15 horsepower, 1.5 cents per kWh at 40 horsepower, 1.25 cents per kWh at 100 horsepower, and 1.0 cents per kWh for 200 or more horsepower. An operating load averaging 100 per cent of the installed horsepower is also assumed. If the estimator concludes that the unit power cost or operating load applicable to a specific situation will vary significantly from these values, the estimated power cost should be adjusted accordingly.

Figure 78, Page 236, shows material and supply cost estimates for chlorination based on annual chlorine use. The estimated cost of chlorine is shown separately from other material and supply costs.

Other material and supply costs include the materials and parts to keep the chlorination facilities in proper operating condition. It also includes the utility costs required to operate the feeders and associated equipment, and to heat the building in which the facilities are located.

APPLICATION OF OPERATION AND MAINTENANCE COST ESTIMATING DATA

Table 18, Page 228, presents a form prepared for the purpose of estimating operation and maintenance costs of a wastewater stabilization pond. It is assumed that the estimator will have determined from preliminary design the required parameters of the cost components and, based upon this premise, the total operation and maintenance cost may be estimated.

Table 18-A, Page 229, illustrates the use of the cost data developed in this report for estimating total operation and maintenance cost of a wastewater stabilization pond. The example is based upon a hypothetical nonaerated stabilization pond with an average design capacity of 1.0 million gallons per day. The sizes of individual cost components and quantities shown for the example are representative of average conditions which may be encountered for the assumed facility. However, since variations in the sizes of respective components and quantities may be significant, due to differences in local conditions, the total cost indicated in the example may not be representative for any particular 1.0 mgd installation.

The estimating form presented in Table 18 requires the application of the average local labor rate to payroll man-hours to develop estimated total direct labor costs. This labor rate may vary significantly throughout the country, and is subject to inflationary influences.

The National Average Earning Rate published by the U. S. Department of Labor, Bureau of Labor Statistics, for nonsupervisory employees in the public utility industry, under "Water, Steam, and Sanitary Systems", SIC Code 494-7, as of January 1971 is $3.68 per hour. It is estimated that inclusion of supervisory personnel in the average would raise the average hourly rate to approximately $3.85. Local conditions and inflationary increases should be recognized in developing total labor cost estimates. The $4.10 per man-hour direct labor cost shown in Table 18-A is assumed applicable for the example stabilization pond.

The limitations of cost estimates based upon average conditions are again emphasized. Operation and maintenance cost data presented herein are applicable as a basis of preliminary estimates for planning requirements and methods, and for general comparative cost studies of alternative wastewater treatment methods. These data, unadjusted for particular local conditions, cannot be used for operation and maintenance cost estimates at specific locations. This cost estimate source does not supplant the need for individual engineering studies of project costs.

TABLE 18

ESTIMATED ANNUAL OPERATION AND MAINTENANCE COST

Project ____________; Computed By ____________; Date ________

PART A - LABOR COSTS

Cost Component	Component Parameter	Estimated Annual Payroll Man-Hour Requirements			
		Reference Figure No.	Operation man-hours	Maintenance man-hours	Total man-hours
Operation and Maintenance Labor:					
Nonaerated Stabilization Pond	____ acres water surface area	72 & 73	____	____	____
Aerated Stabilization Pond	____ acres water surface area	74	____	____	____
Chlorination	____ tons per year chlorine use	75	____	____	____
____	____	____	____	____	____
____	____	____	____	____	____
____	____	____	____	____	____
Total Operation and Maintenance Labor			____	____	____
Administration and General Labor	10% of Total Operation and Maintenance Labor				____
Total Estimated Annual Payroll Man-Hour Requirements					____
Total Estimated Direct Payroll Labor Costs at $____ per Man-Hour					$____
Estimated Indirect Labor Costs at ____ % of Direct Labor Costs					$____
Total Estimated Labor Costs					$____

PART B - MATERIAL AND SUPPLY COSTS

		Estimated Material and Supply Costs			
		Reference Figure No.	Power or Chemicals $/year	Other $/year	Total $/year
Nonaerated Stabilization Pond	____ acres water surface area	76	____	____	____
Aerated Stabilization Pond	____ horsepower total installed capacity	77	____	____	____
Chlorination	____ tons per year chlorine use	78	____	____	____
____	____	____	____	____	____
____	____	____	____	____	____
____	____	____	____	____	____
Total Estimated Material and Supply Costs at January, 1971 Cost Level					____
Trended Total Estimated Material and Supply Costs ____ % Trend Factor (See note below)					____

PART C - TOTAL ANNUAL COSTS

Total Estimated Labor Costs (from Part A)	____
Trended Total Estimated Material and Supply Costs (from Part B)	____
Total Estimated Operation and Maintenance Cost	____

Note:

$$\text{Trend Factor} = \frac{\text{Wholesale Price Index for Industrial Commodities as of Applicable Date}}{\text{Wholesale Price Index for Industrial Commodities as of January, 1971}} = \frac{\_\_\_\_}{112.2} = \_\_\_\_\%$$

TABLE 18-A

ESTIMATED ANNUAL OPERATION AND MAINTENANCE COST

Project *Highville, Kansas* ; Computed By *RWB* ; Date *Sept 1971*

PART A - LABOR COSTS

Cost Component	Component Parameter	Estimated Annual Payroll Man-Hour Requirements: Reference Figure No.	Operation man-hours	Maintenance man-hours	Total man-hours
Operation and Maintenance Labor:					
Nonaerated Stabilization Pond	*57* acres water surface area	72 & 73	*550*	*430*	*980*
Aerated Stabilization Pond	____ acres water surface area	74			
Chlorination	____ tons per year chlorine use	75			
Total Operation and Maintenance Labor			*550*	*430*	*980*
Administration and General Labor	10% of Total Operation and Maintenance Labor				*100*
Total Estimated Annual Payroll Man-Hour Requirements					*1,080*
Total Estimated Direct Payroll Labor Costs at $ *4.10* per Man-Hour					$ *4,430*
Estimated Indirect Labor Costs at *15* % of Direct Labor Costs					$ *660*
Total Estimated Labor Costs					$ *5,090*

PART B - MATERIAL AND SUPPLY COSTS

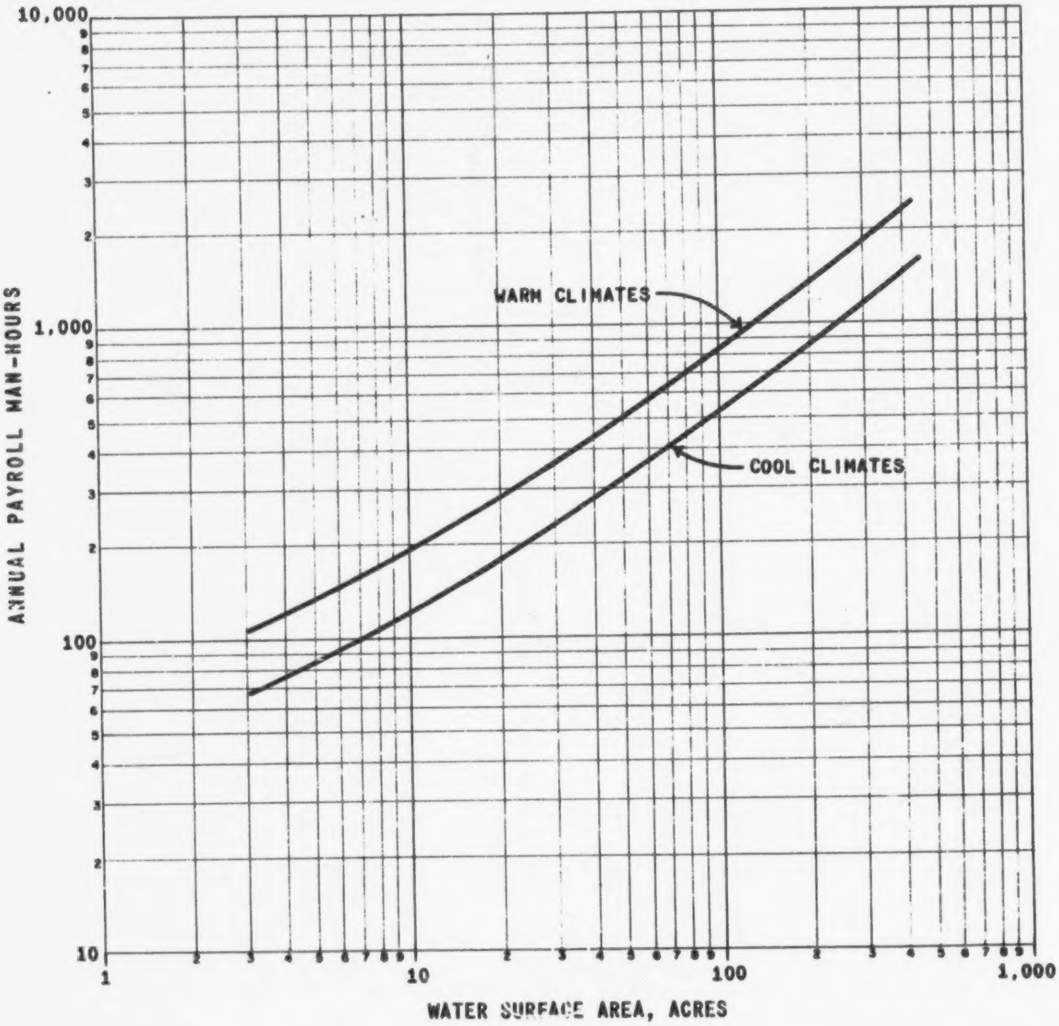
		Estimated Material and Supply Costs: Reference Figure No.	Power or Chemicals $/year	Other $/year	Total $/year
Nonaerated Stabilization Pond	*57* acres water surface area	76		*1,200*	*1,200*
Aerated Stabilization Pond	____ horsepower total installed capacity	77			
Chlorination	____ tons per year chlorine use	78			
Total Estimated Material and Supply Costs at January, 1971 Cost Level					*1,200*
Trended Total Estimated Material and Supply Costs *102.5* % Trend Factor (See note below)					*1,230*

PART C - TOTAL ANNUAL COSTS

Total Estimated Labor Costs (from Part A)	*5,090*
Trended Total Estimated Material and Supply Costs (from Part B)	*1,230*
Total Estimated Operation and Maintenance Cost	*6,320*

Note:

Trend Factor = $\frac{\text{Wholesale Price Index for Industrial Commodities as of Applicable Date}}{\text{Wholesale Price Index for Industrial Commodities as of January, 1971}} = \frac{\_\_\_\_}{112.2} = \_\_\_\_\%$



WASTEWATER STABILIZATION PONDS

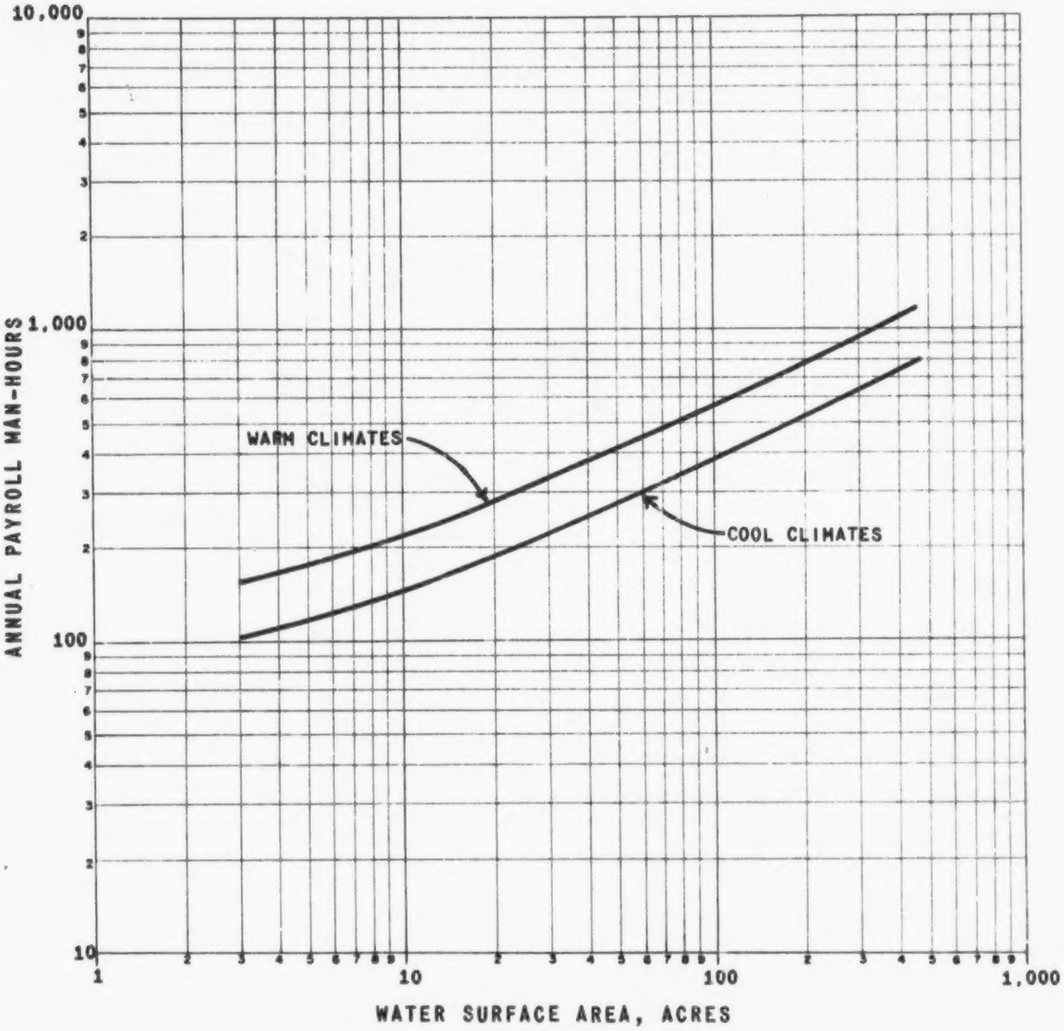
NONAERATED PONDS
OPERATION LABOR
MAN-HOUR REQUIREMENTS

OPERATION AND MAINTENANCE COSTS

WATER QUALITY OFFICE
ENVIRONMENTAL PROTECTION AGENCY

BLACK & VEATCH
CONSULTING ENGINEERS
1971

FIGURE 72



WASTEWATER STABILIZATION PONDS

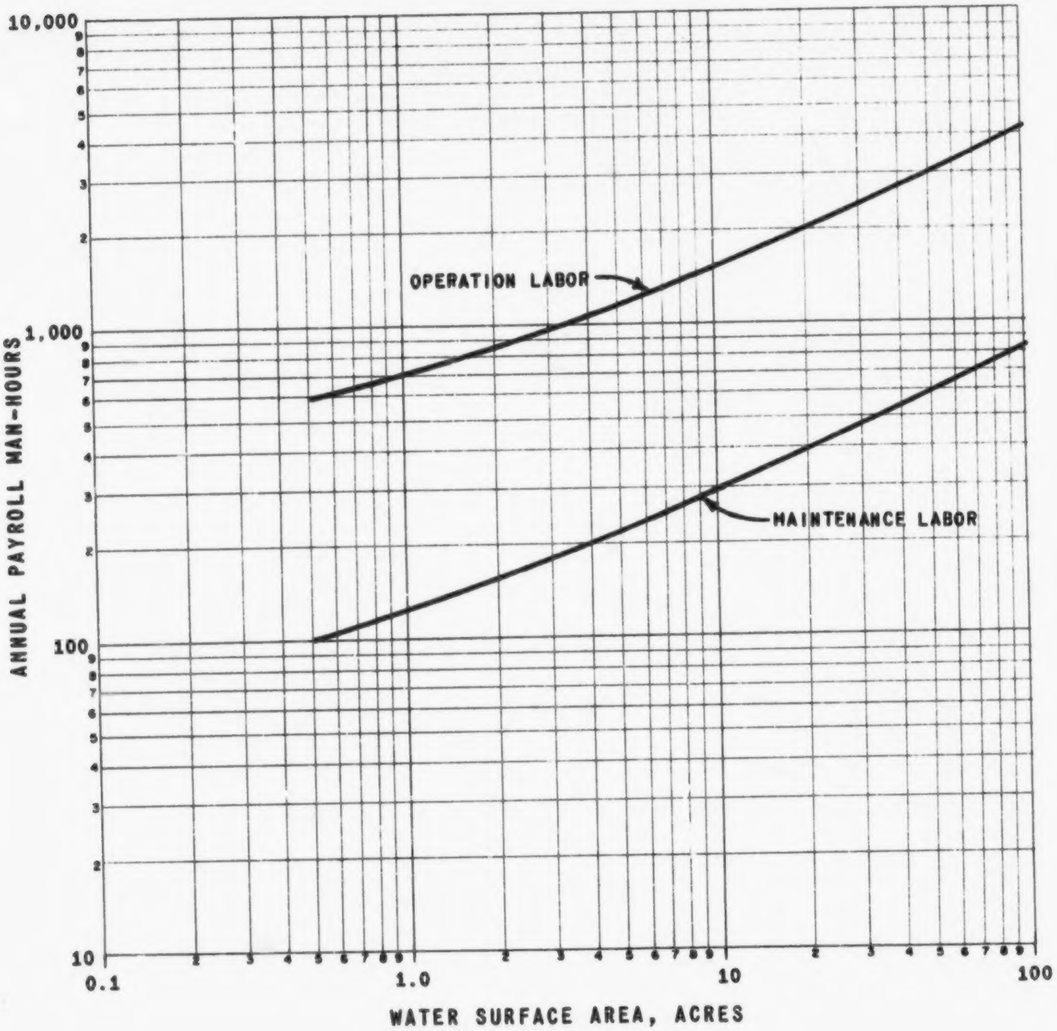
NONAERATED PONDS
MAINTENANCE LABOR
MAN-HOUR REQUIREMENTS

OPERATION AND MAINTENANCE COSTS

WATER QUALITY OFFICE
ENVIRONMENTAL PROTECTION AGENCY

BLACK & VEATCH
CONSULTING ENGINEERS
1971

FIGURE 73



WASTEWATER STABILIZATION PONDS

AERATED PONDS
OPERATION AND MAINTENANCE LABOR
MAN-HOUR REQUIREMENTS

OPERATION AND MAINTENANCE COSTS

WATER QUALITY OFFICE
ENVIRONMENTAL PROTECTION AGENCY

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CONSULTING ENGINEERS
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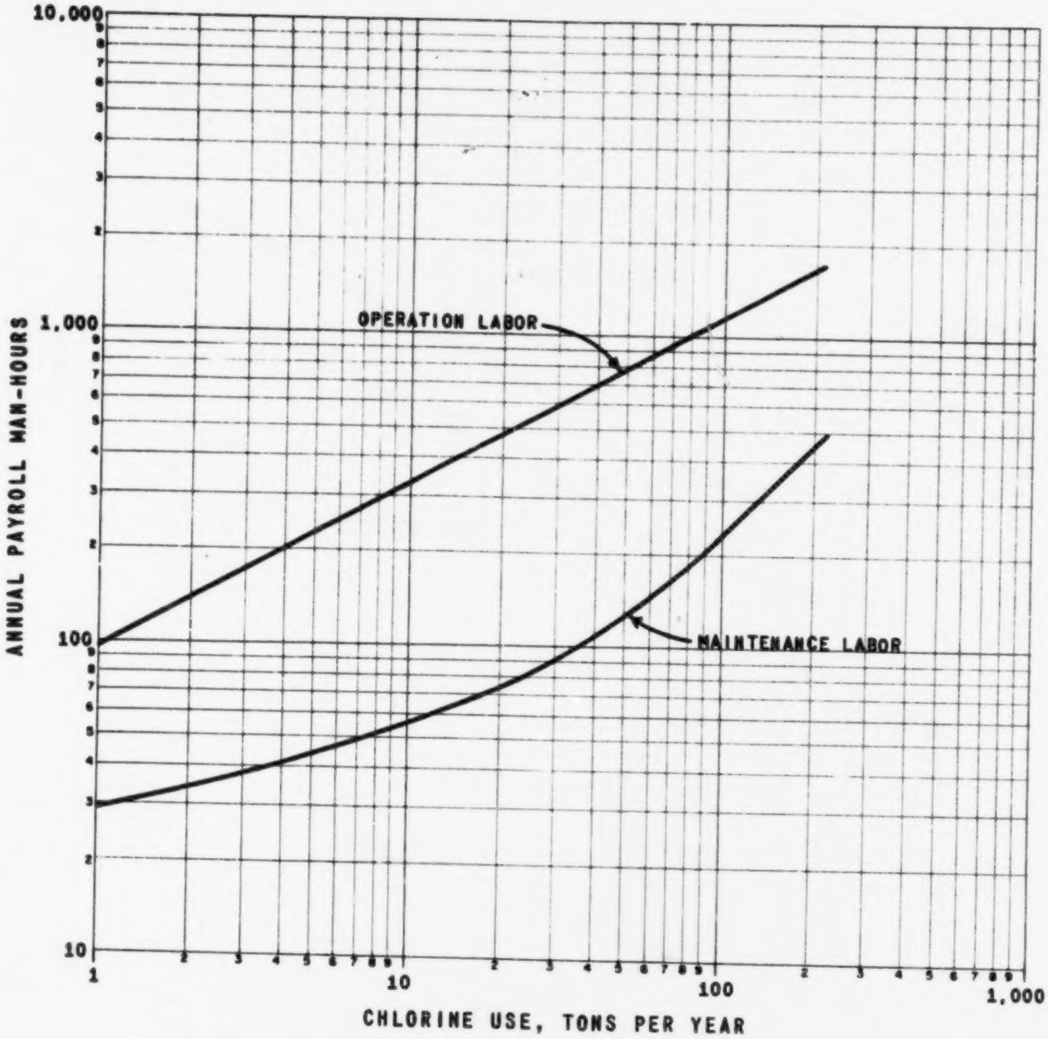
FIGURE 74



WASTEWATER STABILIZATION PONDS

CHLORINATION
OPERATION AND MAINTENANCE LABOR
MAN-HOUR REQUIREMENTS

OPERATION AND MAINTENANCE COSTS

WATER QUALITY OFFICE
ENVIRONMENTAL PROTECTION AGENCY

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CONSULTING ENGINEERS
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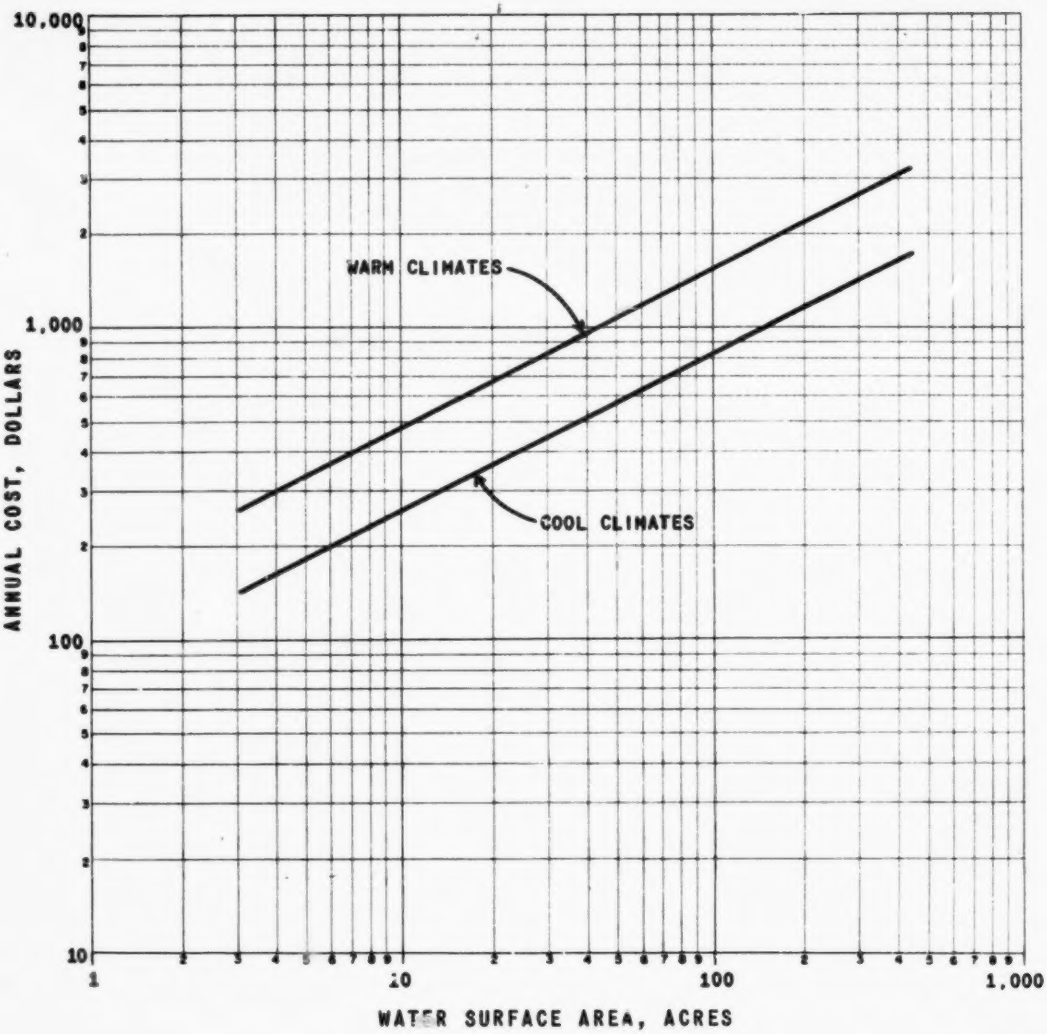
FIGURE 75



WASTEWATER STABILIZATION PONDS

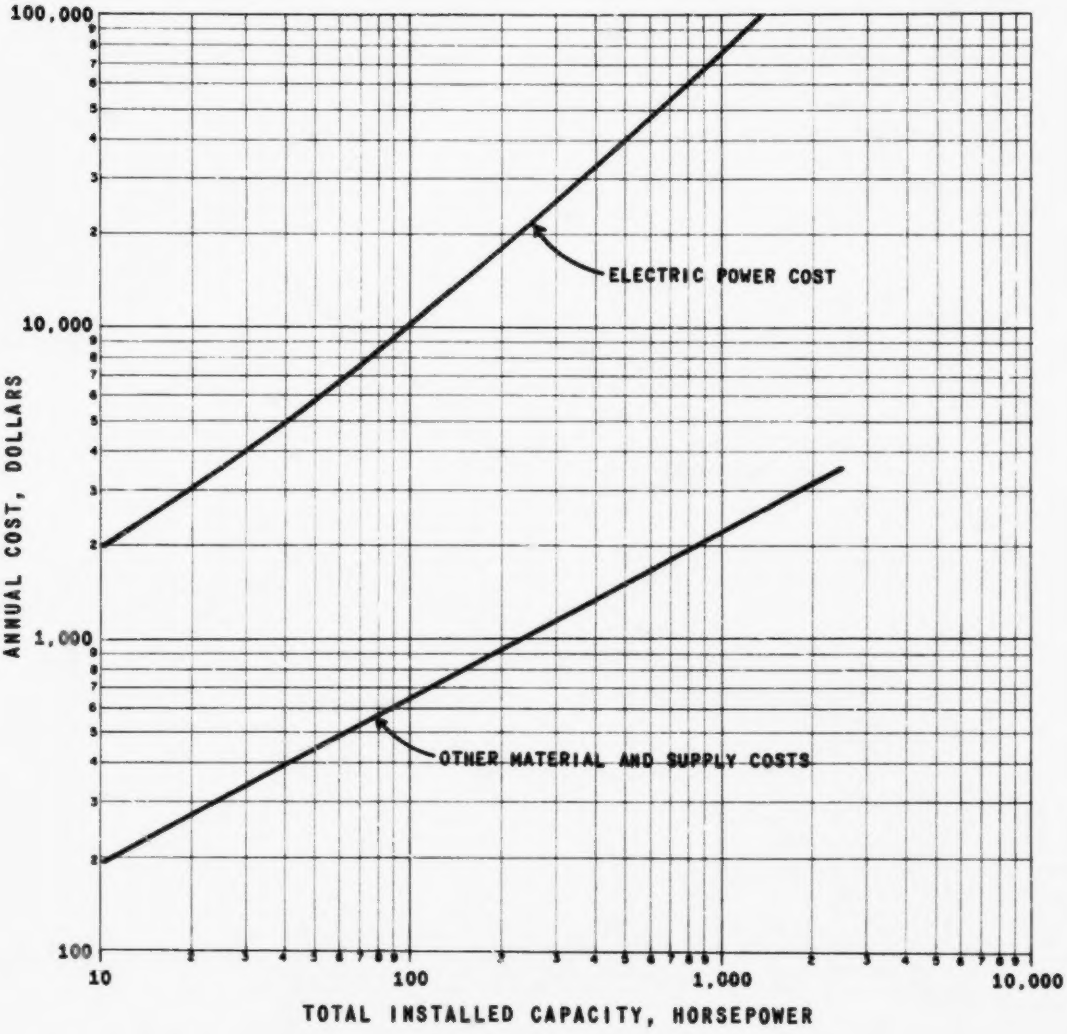
NONAERATED PONDS
MATERIAL AND SUPPLY COSTS

OPERATION AND MAINTENANCE COSTS

WATER QUALITY OFFICE
ENVIRONMENTAL PROTECTION AGENCY

BLACK & VEATCH
CONSULTING ENGINEERS
1971

FIGURE 76



WASTEWATER STABILIZATION PONDS

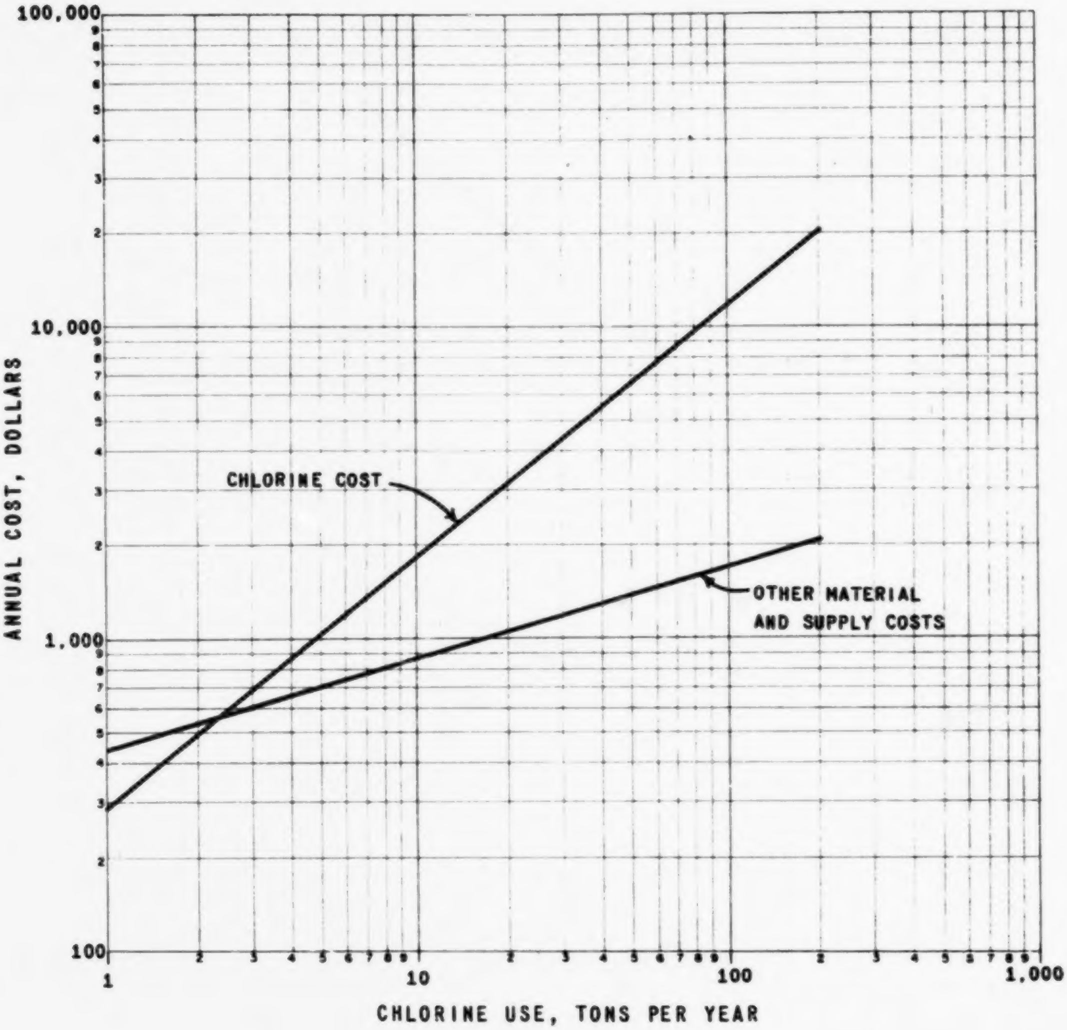
AERATED PONDS
MATERIAL AND SUPPLY COSTS

OPERATION AND MAINTENANCE COSTS

WATER QUALITY OFFICE
ENVIRONMENTAL PROTECTION AGENCY

BLACK & VEATCH
CONSULTING ENGINEERS
1971

FIGURE 77



WASTEWATER STABILIZATION PONDS

CHLORINATION
MATERIAL AND SUPPLY COSTS

OPERATION AND MAINTENANCE COSTS

WATER QUALITY OFFICE
ENVIRONMENTAL PROTECTION AGENCY

BLACK & VEATCH
CONSULTING ENGINEERS
1971

FIGURE 78

SECTION IV

MANPOWER REQUIREMENTS

This section presents a basis and method for estimating total manpower requirements and plant staffing for wastewater stabilization ponds when used as the only treatment process. Also included are occupation descriptions applicable to personnel commonly required for operation and maintenance of such facilities.

The information presented is to assist those seeking to project future wastewater treatment plant staffing requirements as a basis for planning of manpower training programs. The report can also be utilized as a guide to staffing requirements of individual wastewater stabilization pond installations, providing recognition is given to the average nature of the estimating data presented, and judgment is applied regarding specific local circumstances.

The principal bases for preparation of the information presented are field investigations of 38 operating wastewater stabilization ponds of various types and sizes located in 27 communities throughout the country, and the experience and judgment of the investigators. Background information regarding field investigations and the use of estimating data developed is presented in Part Four, Section III of the report, on Pages 221 and 222.

OCCUPATION DESCRIPTIONS

For procedures of estimating wastewater stabilization pond staffing requirements to be meaningful to a broad group of engineers, administrators, and others, it is necessary to have relatively standard definitions of staff positions. Occupation descriptions for three types of personnel commonly employed to operate and maintain such facilities have been prepared.

Occupation descriptions developed for all major job titles commonly involved in the operation and maintenance of conventional wastewater treatment plants ranging in size from 1 to 100 million gallons per day, are presented on Pages 145 through 196 of Part Three of this report. The background of the development of these descriptions is presented on Pages 121 and 122. Additional occupation descriptions have been developed for job titles applicable to personnel required for operation and maintenance of wastewater stabilization ponds. The job titles of Superintendent, Operator, and Laborer, are described on Pages 243 through 248 of this report.

Because of the nominal time required of employees in each of the respective job classifications to operate and maintain wastewater stabilization ponds, it is not believed warranted to employ or train personnel to specifically fill these positions. Rather, the occupation descriptions may be best utilized as guides in selecting or assigning employees from an existing work force to perform the tasks necessary to properly operate and maintain such facilities.

TOTAL MANPOWER REQUIREMENTS AND PLANT STAFFING

The total manpower requirement for a particular wastewater stabilization pond covered herein is for all personnel required for adequate operation and maintenance of the facility. A means of estimating total annual payroll man-hour requirements for individual ponds is developed in Part Four, Section III of this report. Graphical relationships of total annual man-hour requirements, for both operation and maintenance duties, to appropriate sizing parameters are presented for nonaerated ponds, aerated ponds, chlorination, and administration and general.

The estimates of average annual payroll man-hours for operation and maintenance, respectively, are indicative of the total requirement for personnel to operate and maintain the facility. Man-hour requirements are based on a normal payroll year consisting of [illegible]2 weeks at 40 hours per week, or a total of 2,080 hours per year. Effective working time is estimated to be 90 per cent of the payroll man-hours, with the remaining 10 per cent representing paid vacations, holidays, sick time, and other paid time away from the job.

The estimates of labor requirements for operation and maintenance of wastewater stabilization ponds reflect the use of employees on a part-time basis where the time of employees devoting full efforts to this work cannot be effectively utilized. It must be recognized that the estimates of payroll man-hour requirements shown are only representative of requirements, and are a valid basis of staffing only if the man-hours can be obtained efficiently, with any balance of an employee's time available to be used effectively elsewhere.

Table 18 on Page 228, presents a form for summarizing estimated annual payroll man-hour requirements, and labor costs, for individual wastewater stabilization pond projects. Estimates of total man-hour requirements, developed as indicated by Table 18, may be summarized and used as guides to staffing of such facilities. Table 19, on the following page, provides a form for this purpose. As indicated on the table, the total number of full-time employees required may be estimated by dividing total payroll man-hours by 2,080, the number of hours in the normal payroll year.

TABLE 19
ESTIMATED WASTEWATER STABILIZATION POND STAFFING COMPLEMENT

Project ____________________; Computed By ___________; Date ____________

Staff Position	Estimated Annual Payroll Requirements		Suggested Staffing
	Man-Hours[a]	Number of Employees[b]	Number of Employees
Superintendent	_________(c)	_________	_________
Operator			
Laborer			_________
Subtotal	_________(d)	_________	_________
Total Labor Requirements	_________	_________	_________

Notes:

(a) From Table 18
(b) Man-hours divided by 2,080 hours per year
(c) Administration and general man-hours
(d) Operation and maintenance man-hours

Upon determination of the approximate number of employees in each category, the suggested staffing is developed on a judgment basis. The division of the number of employees in the suggested staffing among staff positions may not necessarily agree with the division of payroll man-hours. The difference would result from practical considerations and the fact that an operator may perform all or part of the maintenance tasks or, conversely a laborer may be responsible, under a superintendent for the pond operations, depending upon the size of the facility.

The suggested staffing will usually include part-time personnel and be dependent on availability of part-time employees.

Table 19-A illustrates the use of the estimated annual payroll requirement data in developing a suggested plant staff complement. The example is based on a nonaerated wastewater stabilization pond having a 1.0 million gallon per day design capacity, as used in previous examples in Part Four of this report.

TABLE 19-A

ESTIMATED WASTEWATER STABILIZATION POND STAFFING COMPLEMENT

Project *Highville, Kansas* ; Computed By *RMB* ; Date *Sept. 1971*

Staff Position	Estimated Annual Payroll Requirements		Suggested Staffing
	Man-Hours[(a)]	Number of Employees[(b)]	Number of Employees
Superintendent	100 (c)	0.1	0.1
Operator			0.3
Laborer			0.2
Subtotal	980 (d)	0.5	
Total Labor Requirements	1080	0.6	0.6

Notes:

(a) From Table 18-A
(b) Man-hours divided by 2,080 hours per year
(c) Administration and general man-hours
(d) Operation and maintenance man-hours

EXAMPLES OF WASTEWATER STABILIZATION POND STAFFING

Examples of wastewater stabilization pond staff complements, developed in accord with the procedures previously set forth, are shown in Table 20 for 6 differing pond situations. Complements for ponds ranging from 0.1 to 10.0 mgd average capacity are included as guidelines for estimating staff requirements on a national average basis.

The magnitude of the parameter used in estimating payroll man-hours for each component was estimated on the bases of average design criteria. It must be recognized that a specific pond may not have all components sized in accord with these averages, and the examples may not be applicable to any particular situation.

The staff complements shown are based on the assumption that employees will be utilized for stabilization pond functions on a part-time basis, and are flexible in their capabilities and willingness to perform a variety of tasks. A single employee may perform a majority of the needed operation and maintenance functions for the smaller installations.

TABLE 20

STAFF COMPLEMENTS FOR WASTEWATER STABILIZATION PONDS

Occupation Title	Pond Average Day Capacity, mgd				
	0.1	0.5	1.0	5.0	10.0
	Estimated Number of Personnel				
Nonaerated ponds without chlorination					
Cool Climate:					
Superintendent	0.1	0.1	0.1	0.1	0.1
Operator	-	-	-	0.5	1.0
Laborer	0.1	0.2	0.3	0.3	0.4
Total	0.2	0.3	0.4	0.9	1.5
Warm Climate:					
Superintendent	0.1	0.1	0.1	0.1	0.2
Operator	-	-	0.3	1.0	1.0
Laborer	0.1	0.3	0.2	0.3	1.1
Total	0.2	0.4	0.6	1.4	2.3
Nonaerated ponds with chlorination					
Cool Climate:					
Superintendent	0.1	0.1	0.1	0.1	0.2
Operator	-	-	0.3	1.0	1.0
Laborer	0.1	0.3	0.2	0.4	1.3
Total	0.2	0.4	0.6	1.5	2.5
Warm Climate:					
Superintendent	0.1	0.1	0.1	0.2	0.3
Operator	-	0.2	0.5	1.0	1.0
Laborer	0.2	0.2	0.2	0.8	2.0
Total	0.3	0.5	0.8	2.0	3.3
Aerated ponds without chlorination					
Superintendent	0.1	0.1	0.1	0.1	0.2
Operator	0.3	0.5	0.5	1.0	1.0
Laborer	-	-	0.2	0.2	0.7
Total	0.4	0.6	0.8	1.3	1.9
Aerated ponds with chlorination					
Superintendent	0.1	0.1	0.1	0.2	0.3
Operator	0.4	0.5	0.5	1.0	1.0
Laborer	-	0.2	0.4	0.8	1.5
Total	0.5	0.8	1.0	2.0	2.8

OCCUPATION DESCRIPTION

Title: SUPERINTENDENT, STABILIZATION POND

JOB DESCRIPTION

Responsible for administration, operation, and maintenance of pond. Organizes and directs activities of personnel. Periodically inspects pond, structures, and equipment. Analyzes and evaluates operation and maintenance functions, initiates or recommends new or improved practices. Develops plans and procedures to insure efficient operation of pond and provide for future requirements. Recommends improvements and additions. Review data and prepares or reviews and approves operation reports and budget requests. Recommends specifications for major purchases. Maintains effective communications and working relationships with employees, government officials, and general public.

QUALIFICATIONS PROFILE

1. Formal Education
   High school graduate or equivalent. College level business or engineering courses desirable.

2. General Requirements
   a. Understanding of managerial, administrative, and accounting practice and procedures.
   b. Ability to prepare or supervise preparation of clear, concise reports and budget recommendations.
   c. Ability to plan, direct, and evaluate pond operation and maintenance functions.
   d. Ability to establish and maintain effective communication and working relationships.
   e. Ability to perform and instruct others in performance of simple laboratory tests.
   f. General knowledge of processes involved and equipment used in pond operation.

3. General Educational Development
   a. Reasoning
      Apply principles of logic to define problems, collect and analyze data, and draw valid conclusions. Deal with a variety of concrete and abstract variables.
   b. Mathematical
      Perform ordinary arithmetical procedures in standard, practical applications.

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Title: SUPERINTENDENT (Cont'd)

c. Language
  (1) Write and edit operations reports.
  (2) Interview applicants and employees.
  (3) Establish and maintain communications with employees, government officials, and the public.

4. Specific Vocational Preparation

One to 3 years administrative experience depending on educational background and size of operation. Supervisory experience highly desirable.

5. Aptitudes - Relative to General Working Population

a. Intelligence)
b. Verbal) Middle third
c. Numerical)
d. Form Perception) Lowest third excluding
e. Spatial) bottom 10 per cent
f. Clerical Perception) Middle third
g. Motor Coordination)
h. Finger Dexterity) Lowest third excluding
i. Manual Dexterity) bottom 10 per cent
j. Eye-Hand-Foot Coordination)
k. Color Discrimination)

6. Interests

Prefer working with people in situations involving organization and supervision of varied activities.

7. Temperament

Prefer situations involving the direction, control, and planning of an entire activity or the activity of others.

8. Physical Demands

Sedentary work, except for regular pond inspections.

9. Working Conditions

Largely inside. Occasional exposure to weather and odors and risk of bodily injury. Possible exposure to toxic conditions.

ENTRY SOURCES: Job will usually be part-time duty of Water and/or Sewer Superintendent, City Engineer, or Director of Public Works. Qualified Operator may act as Superintendent. Full time Pond Superintendents are not anticipated.

OCCUPATION DESCRIPTION

Title: OPERATOR, STABILIZATION POND

JOB DESCRIPTION

Performs any combination of tasks such as following, under general direction of Superintendent: Inspects condition of pond, dikes, fence, and gates. Inspects influent, transfer, and effluent structures and equipment. Adjusts water level in cells. Adjusts flow to cells, if pond has multiple cells. Operates aeration equipment, if used. Checks temperature of pond contents and flow rate of effluent (in larger ponds). Collects samples for testing. Performs simple chemical and physical tests. Fills out report forms including comments on condition of pond. Performs laborer tasks in absence of laborer.

QUALIFICATIONS PROFILE

1. Formal Education
   Ability to read and to prepare simple written reports. Understand sufficient arithmetic to perform simple tests and accurately record results. High school courses desirable.

2. General Requirements
   a. Ability to learn proper methods for operating pond and equipment.
   b. Ability to perform simple tests, evaluate results, and maintain records and reports.

3. General Educational Development
   a. Reasoning
      Apply common sense understanding to carry out written, oral, or diagrammatic instructions. Deal with problems involving concrete variables in standardized situations.
   b. Mathematical
      Perform ordinary arithmetic calculations.
   c. Language
      Ability to comprehend oral and written instructions, record information, prepare reports, and request supplies and work materials orally or in writing.

4. Specific Vocational Preparation
   On-the-job training from date of employment. Previous experience as laborer or automotive equipment operator desirable. Valid vehicle operator's license a prerequisite, if required.

Title: OPERATOR (Cont'd)

5. Aptitudes - Relative to General Working Population

a. Intelligence	Lowest third, excluding bottom 10 per cent
b. Verbal	
c. Numerical	
d. Spatial	
e. Form Perception	
f. Clerical Perception	
g. Motor Coordination	
h. Finger Dexterity	
i. Manual Dexterity	Middle third
j. Eye-Hand-Foot Coordination	
k. Color Discrimination	

6. Interests

   Prefer routine, concrete, organized activities dealing with things and objects.

7. Temperament

   Worker must adjust to a variety of duties, including evaluation of information against measurable criteria.

8. Physical Demands

   Medium work; involving balancing, stooping, kneeling, crouching, reaching, handling, fingering, hearing, visual acuity, depth perception, and color vision.

9. Working Conditions

   Primarily outside. Exposed to weather and odors. May be exposed to toxic conditions. Possible risk of bodily injury.

ENTRY SOURCES: Job will usually be part-time duty of employee of the Water, Sewage, or Public Works Departments. Operator may also act as Superintendent or Laborer. Full-time Pond Operators are not anticipated.

PROGRESSION TO: Superintendent, Stabilization Pond.

OCCUPATION DESCRIPTION

Title: LABORER, STABILIZATION POND

JOB DESCRIPTION

Performs any combination of following tasks, as directed by Superintendent or Operator: Mows grass and removes cut grass from water and dike at water line. Removes scum, floating grease balls, or debris from pond and hauls to disposal site. Repairs dike erosion. Paints and repairs structures, fences, gates, and equipment. Operates motor boat to disperse floating algae mats or scum. Removes sludge from end of influent line(s). Drives equipment used at the pond such as a pickup, dump truck, tractor, and mower. Helps perform minor maintenance on equipment used at pond. Assists in duties of Operator and acts as a relief operator.

QUALIFICATIONS PROFILE

1. Formal Education
   Ability to speak, read, and write English. Elementary school education desirable.

2. General Requirements
   a. Ability to follow instructions and read directions.
   b. Ability to perform routine tasks without constant direct supervision.

3. General Educational Development
   a. Reasoning
      Apply common sense understanding to carry out simple instructions.
   b. Mathematical
      Perform simple addition and subtraction.
   c. Language
      Ability to understand oral or written instructions and request supplies and materials orally or in writing.

4. Specific Vocational Preparation
   On-the-job training or previous experience as a laborer. Valid vehicle operator's license a prerequisite, if required.

Title: LABORER (Cont'd)

5. Aptitudes - Relative to General Working Population
    - a. Intelligence)
    - b. Verbal)
    - c. Numerical) Lowest third excluding
    - d. Spatial) bottom 10 per cent
    - e. Form Perception)
    - f. Clerical Perception)
    - g. Motor Coordination)
    - h. Finger Dexterity)
    - i. Manual Dexterity) Middle third
    - j. Eye-Hand-Foot Coordination)
    - k. Color Discrimination)

6. Interests

   Preference for activities dealing with things and objects.

7. Temperament

   Worker must adjust to situations involving doing things only under specific instruction, allowing little or no room for independent action or judgment in working out job problems.

8. Physical Demands

   Medium to heavy work. Involves lifting heavy objects, climbing, balancing, stooping, kneeling, crouching, crawling, reaching, and handling.

9. Working Conditions

   Primarily outside. No protection from weather. Subject to noise and vibration hazards, odors, and toxic conditions.

ENTRY SOURCES: Job will usually be part-time duty of employee of the Water, Sewage, or Public Works Departments. Qualified laborer may also act as Operator. Full-time Pond Laborers are not anticipated.

PROGRESSION TO: Operator, Stabilization Pond.

ACKNOWLEDGMENTS

This opportunity is taken to express appreciation for the excellent cooperation of the many organizations and individuals providing information essential to this study. Regional offices of the Environmental Protection Agency and agencies responsible for water pollution control in each of the various states were most helpful in arranging for field investigations. Department heads, managers, superintendents, and operating personnel in each of the cities where field investigations of wastewater treatment facilities were undertaken are extended particular acknowledgment for their cooperation and effort. Representatives of various manufacturers of wastewater treatment equipment furnished considerable information that was valuable in estimating equipment capabilities, purchase cost, and operation and maintenance requirements.

The continued assistance and cooperation throughout the study of Mr. Walter McMichael, Project Officer, Environmental Protection Agency, Cinncinati, Ohio has been very much appreciated.

GLOSSARY

A number of terms used in the preceding discussions have meanings specifically applicable to this report. To obviate misunderstanding, definitions applicable are those presented in the "Glossary - Water and Wastewater Control Engineering", prepared in 1969 by the Joint Editorial Board representing the American Public Health Association, American Society of Civil Engineers, American Water Works Association, and Water Pollution Control Federation. Definitions of additional terms used in this report are as follows:

Average plant flow - The annual volume of wastewater treated, usually expressed in terms of million gallons per day.

Conventional wastewater treatment plant - Those facilities commonly used to provide primary and/or secondary treatment of wastewater.

Debt securities - General obligation or revenue bonds.

Occupation description - A description of job duties, responsibilities, and pre-requisite qualifications related to a specific occupation title, and developed in conformance with the Dictionary of Occupational Titles, published by the United States Department of Labor.

Occupation title - The title denoting a specific occupation description.

Plant component - A major individual treatment facility which singly, or in combination, constitute a wastewater treatment plant.

Sludge heat value - The heat of combustion of wastewater sludge.

Sludge stratification - Separation of solids and supernatant in sludge holding tank.

Staff complement - The on-site employees required to properly operate and maintain a wastewater treatment plant.

Total labor cost - Direct salary and wage costs plus indirect labor related costs such as social security, pension fund contributions, and insurance premiums.

Trickling filter ponding - A condition occurring when voids in filter media become clogged with excessive growth of organisms, which prevents the free flow of the wastewater.

Wastewater strength - The concentration of pollutants in wastewater, usually expressed in terms of milligrams per liter.

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SELECTED WATER RESOURCES ABSTRACTS

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3. Accession No.

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4. Title

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15. Supplementary Notes

Final Report, 250 pages, 78 figures, 20 tables

16. Abstract

Data for estimating average construction costs, operation and maintenance costs, and manpower staffing requirements, are presented for conventional wastewater treatment plants ranging from 1 to 100 mgd in capacity, and for stabilization ponds ranging from 0.1 to 10 mgd in capacity. Estimating data are included for [illegible]1 separate components of conventional plants and 6 separate components of stabilization ponds. Examples of use of the data are given.

Estimated average construction costs and operation and maintenance costs are related graphically to appropriate single parameters for respective plant components. Occupation descriptions for 24 job titles related to wastewater treatment, developed in accordance with standards of the Dictionary of Occupational Titles, are included in the report.

The data presented provide means of estimating costs and staffing requirements for a variety of conventional wastewater treatment facilities on an average basis, but do not supplant the need for detailed study of local conditions or recognition of changing design requirements in preparing estimates for specific application.

This report was submitted in fulfillment of Project Number 17090DAN, Contract Number 14-12-462, under sponsorship of the Environmental Protection Agency.

17a. Descriptors

*Construction Costs, *Operating Costs, *Maintenance Costs, *Wastewater Treatment, Capital Costs, Manpower

17b. Identifiers

*Occupation Descriptions, *Process Costs, Staffing Requirements

17c. COWRR Field & Group 05 D

18. Availability

19. Security Class. (Report)

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